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ABSTRACT

This collection of curriculum guides sets forth curriculum plans for teaching concepts in several areas relating to science, environment, and technology. The topics covered individually in this collection include: Air Pollution, Solid Waste Disposal, Data Technology - A Pollutant, Power Generation, and Noise Pollution. Each section includes a reference list providing additional sources of reading or audio-visual material. (RE)

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MODERN TECHNOLOGY

Curriculum Material for a
Community College Level Course

Marian Visich, Jr.
Editor

The support of the National Science Foundation in the preparation of this report through Grant GY-6185 is gratefully acknowledged.

POLYTECHNIC INSTITUTE OF BROOKLYN
Department
of
Aerospace Engineering and Applied Mechanics
January 1973

SE 029 050

FOREWORD

In April 1969, the National Science Foundation awarded the Polytechnic Institute of Brooklyn a Grant (GY 6185) for the development of curriculum material for a course in modern technology appropriate for two-year colleges. The basic objective of the course is to provide non-science students an introductory understanding of modern technology.

To capitalize on the enthusiastic support of several two-year colleges in the State of New York in the preparation of the proposal, it was decided to have teachers from six different two-year colleges in the State of New York participate in the development of the curriculum material and the initial trial of the course. By February 1970 the following two-year colleges had agreed to participate in the project:

1. Nassau Community College
   Professor Andrew Kowalik
   Engineering/Physics/Technology Department

2. Niagara County Community College
   Professor Roger Lehman
   Electrical Technology Department

3. State University of New York
   Agricultural and Technical College at Farmingdale
   Professor Charles Thompson
   Data Processing Department

4. Suffolk County Community College
   Professor Mike Hawryluk
   Physics Department

5. Queensboro Community College
   Professor Gabriel Kousourou
   Electrical Technology Department

The majority of the schools listed above are located within easy travel of the Polytechnic Institute of Brooklyn. They represent a variety of schools with different student bodies.

During the Spring of 1970, the participants in the project received approval of their respective curriculum committees to offer a course on modern technology as a science elective. Listed below are the names of the courses approved by the two-year colleges participating in the program:

1. Nassau Community College
   ENS 111-2 Science of Technology I, II

2. Niagara County Community College
   PHS 448-9 Man and Technology I, II

3. Queensboro Community College
   ET 82 Computers in Modern Society
   ET 83 The Science of Engineering Technology

4. State University of New York
   Agricultural and Technical College at Farmingdale
   DP 101 Basic Computer Concepts

5. Suffolk County Community College
   PY 15-16 Environmental Physics I, II

At the beginning of the 1971-72 academic year the title of the course at Nassau Community College was changed to Science of Man's World.

Because of the different requirements at the various schools it was decided not to develop a highly structured course. The participants in the project agreed that the most promising method of presenting the concepts of modern technology and the impact of technology on society was by the case study approach. As representative of the material presented in the various course offerings, the topical sequence of the Science of Man's World course is listed below:

Science of Man's World I

- a) Introduction to Course
- b) Decision Making and Optimization Techniques
- c) Fundamentals of Ecology
- d) Thermal Energy and Thermal Pollution
- e) Electrical Energy

Science of Man's World II

- a) Air Pollution
- b) Water Pollution
- c) Solid Waste Management
- d) Noise Pollution
- e) Nuclear Energy and Radiation
- f) Light and Laser Applications

Resource modules were developed by the five participants in topics that were presented in the five courses. The present report contains the final version of the resource modules prepared in the following areas:

1. Air Pollution
   Professor Andrew Kowalik
2. Solid Waste Disposal
   Professor Roger Lehman
3. Data Technology
   Professor Charles Thompson
4. Power Generation
   Professor Mike Hawryluk
5. Noise Pollution
   Professor Gabriel Kousourou

It would be of great interest to the project staff in the evaluation of the material if comments on the utilization of the resource modules and suggestions for improvement of the material contained in the modules were transmitted to:

Professor Marian Visich, Jr.
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Farmingdale, New York 11735.

AIR POLLUTION

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Garden City, New York

September 1972

The support of the National Science Foundation in the preparation of this module through Grant GY-6185 to the Polytechnic Institute of Brooklyn is gratefully acknowledged.

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Preliminary Comments

The following material is intended to serve as a guide for instructors that are attempting to introduce air pollution to liberal arts or general studies students. What has been compiled represents the author's opinion of the basic minimum that must be included in providing a comprehensive module. Omission of material has been necessary throughout; however, the attached reference section can be used to complete these gaps as an instructor's need develops.

A selection of laboratory experiments has been included and it should be kept in mind that special equipment will be required to perform these samples. Two laboratory periods totaling six hours of time and nine hours of lecture were devoted to covering the contents. Feedback from students and fellow faculty have been incorporated in selecting the issues discussed and depth of background material presented.

Air Pollution Background

The atmosphere is a dynamic system of gases, solids and liquids that are generated by both nature and man. In addition we know that rather minute traces of pollutants are capable of causing effects upon man, animals and plants. These features of the problem have lead to the generation of precise and elaborate instrumentation but our aim in this module will not be concerned with this aspect. It is to be appreciated however that continuous precise monitoring will be required to prevent harmful effects to man.

As a starting point of reference the study of air pollution might best begin with a consideration of the composition of air. Table 1 lists the gaseous components found by laboratory analysis.

Particulate matter present varies greatly from place to place depending upon activities on the earth's surface while water content varies from 0% to about 5%. Variations in this average composition usually have quite harmful effects, i.e. 10% of CO_2 would be poisonous while 10% CH_4 or H_2 would be explosive. Such major variations however are not what is commonly considered in modern air pollution, but rather it is the gases and particles added in small amounts that modify the overall air quality.

Table 1

Average Gaseous Composition of Natural Dry Air

	Gas	Concentration	
		(ppm)	(by volume)
"Pure" Air	Nitrogen, N_2	780,900	78.09
	Oxygen, O_2	209,400	20.94
	Inert Gases:	9,325	0.93
	Argon (9300 ppm)		
	Neon (18 ppm)		
	Helium (5 ppm)		
	Krypton (1 ppm)		
	Xenon (1 ppm)		
	Carbon Dioxide, CO_2	315	0.03
	Methane, CH_4 (related to carbon cycle)	1	-
	Hydrogen, H_2	0.5	-
Natural Pollutants (caused by solar radiation and lightning)	Oxides of Nitrogen	0.52	
	N_2O (0.5 ppm)		
	NO_2 (0.02 ppm)		
	Ozone, O_3	0.02	

A 1960 United States Public Health Services study listed the major pollutants and their general sources as follows:

Table 2

Sources of Air Pollutants (Million tons/year)

Pollutant	Source			
	Motor Vehicles	Industry	Heating Fuel	Trash Burning
Carbon Monoxide	66	2	2	1
Sulfur Oxides	1	9	3	1
Nitrogen Oxides	6	3	-	1
Hydrocarbons	12	1	1	1
Particulate Matter	1	3	1	1

A review of this table quickly proves the impact that the automobile has upon our national problem. (i.e. CO, NO_2 and HC are the three major air pollutants associated with the internal combustion engine)

Gaseous Air Pollutants

CARBON OXIDES: Carbon dioxide, CO_2, is a normal component in the carbon cycle of our biosphere, however, the burning of fossil fuels has increased the amount in our atmosphere by about 0.7 ppm per year. A continuation of this trend might cause a warming effect world-wide leading to a melting of the polar icecaps and subsequent floodings.

Coal Burning $C + O_2 \longrightarrow CO_2$

Natural Gas $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

Carbon monoxide, CO, is a colorless, odorless and poisonous gas resulting primarily from the inefficient combustion of a fossil fuel.

$2C + O_2 \longrightarrow 2CO$

$2CH_4 + 3O_2 \longrightarrow 2CO + 4H_2O$

While it is known that the CO level is not increasing world wide, it is not known exactly how CO is recycled in the biosphere.

The maximum allowable concentration for healthy individuals in industry working an eight-hour day is 50 ppm. A level of 1000 ppm can produce unconsciousness in 1 hour and death in 4 hours. It has been found that the level inside an automobile moving in a heavy stream of traffic on a multi-lane highway will be about 25 to 50 ppm. Carbon monoxide combines with hemoglobin pigment in blood, therefore, oxygen is displaced and the heart and lungs need to work harder, i.e. 8 hours in an 80 ppm. CO atmosphere results in a 15% blood oxygen carrying capacity;effect equal to losing a pint of blood; traffic jam snarl -- 400 ppm. is common. Symptoms--headache, loss of vision, decreased coordination, nausea, abdominal pain. (New York City street average 9 a.m. - 7 p.m. 15ppm.)

HYDROCARBONS: This family of organic compounds are mainly associated with the incomplete combustion of fossil fuels. Some of these evaporated fuels reacts in the atmosphere with other pollutants in the presence of sunlight to generate photochemical smog. Man presently produces only 15% of world-wide emissions of hydrocarbons, however, he does so in concentrated areas leading to problems. (The natural emissions of hydrocarbons are generated from the natural cycles occurring in plants and forests.) Some hydrocarbon emissions have been listed as carcinogenic.

SULFUR COMPOUNDS: From the standpoint of harmful effects upon man sulfur dioxide, SO_2, is probably the most significant single pollutant. SO_2 is a corrosive and irritating pollutant associated with major air pollution disasters, i.e. London, Donora Pennsylvania, produced by the burning of fuels containing sulfur.

$$S + O_2 \longrightarrow SO_2$$

Such "killer" smogs are dramatic examples of intense pollution, however, much is yet unknown regarding long term, low level exposures. Increased rates of chronic asthma, bronchitis and emphysema have been observed but the complete understanding of the mechanisms is lacking.

Another important sulfur oxide produced in the atmosphere under the influence of sunlight is sulfur trioxide (SO_3). Certain amounts of SO_3 are also generated in

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

combustion processes. Once formed SO_3 reacts with the moisture in the air to form a mist of sulfuric acid. This acid mist then can attack tissue and materials due to the very corrosive nature of this compound.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

A final sulfur compound hydrogen sulfide, H_2S is a colorless, poisonous gas with an associated foul odor. It can readily react with metals resulting in tarnishing and in general weaken materials such as nylon.

NITROGEN COMPOUNDS: Nitrogen dioxide, NO_2, is the major compound in this group of pollutants. This gas has a brownish color, unpleasant odor, and in high concentration can cause effects up to death. Any combustion that occurs in air can generate some oxidation of atmospheric nitrogen.

$$N_2 + O_2 \longrightarrow 2NO$$
$$2NO + O_2 \longrightarrow 2NO_2$$

Nitrogen oxide, NO, which is also formed during combustion is not a major factor due to the fact that NO is readily converted to NO_2 in the air. Recent efforts to reduce the CO and HC emissions of automobiles has led to greater emissions of nitrogen oxides and a need for additional pollution devices to be developed.

OZONE: Ozone, O_3, is a small component of natural air frequently formed by discharges of lightning (0.02ppm). It is a colorless gas with a pungent odor which has been used as an oxidant in many air purifying devices. Industrial sewage plant gases are oxidized using concentrations between 10 to 20 ppm, but such a high level would be fatal to humans. Home devices used for this same purpose have levels of 0.1ppm associated with their operation and as such really do very little to oxidize household odors. It had been hoped that O_3 might be used to combat airborne bacterial agents, however, a recent government study has shown that the level needed to kill bacterial pathogens was killing guinea pigs even more rapidly.*

PHOTOCHEMICAL SMOG: As a result of automobile emissions abundant sunlight, confining topography and suitable wind factors, residents of Los Angeles have become the victims of this airborne chemical reaction. The exact sequence of reactions is not fully understood, however, but the inputs of Ozone, O_3, nitrogen dioxide, NO_2, hydrocarbons, i.e., CH_4, and sunlight have led to the formation of peroxyacetyl nitrate, $C_2H_3O_5N$, which is commonly referred to as photochemical smog. This smog is an irritant to humans, damages plants, and weakens materials such as rubber.

This form of air pollution is not found in all areas, however, the large population concentration of southern California has raised this problem to one of major significance.

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* U.S. Department of H.E. and W., National Air Pollution Control Administration, Air Quality Criteria for Photochemical Oxidants, Washington, D.C., 1970. p.6-18.

Particulate Air Pollution

Airborne "particles" include both solid matter and liquid droplets of varying size and weight. A useful reference to classify particles is the diameter of 1 micrometer (25,400 micrometers = 1 inch). Droplets or solid particles with a diameter of less than 1 micrometer are usually called dust or mists while those greater than 1 micrometer diameter are called grit or drops. Such a system is somewhat arbitrary and it is only used to help organize the rather vague usage of terms in discussing this aspect of air pollution.

Particle size is a major factor in determining the method of removal that should be used. For example, gravitational settling will occur at sizes equal to or greater than 1 micron. Smaller particles must be attacked with such techniques as absorption, electrostatic precipitators, etc.

The effects of airborne particles ranges from mere annoyance to corrosive action on lung tissue depending upon the amount, size and nature of the particles involved. Recently, studies have been performed to show the relationship between airborne dust and increased reflectance of the earth's upper regions. Increased amounts of dust have increased the amount of solar radiation reflected away from the earth which can lead to a world wide cooling. This fact has been somewhat balanced by the heating effects caused by increased CO_2 concentrations. The recent cooling of the earth seems to imply that the particle effect is dominating at this time.

Effects of Air Pollution

DIRECT EFFECTS UPON MAN: The average person breathes 35 pounds of air each day which is six times the amount of food and water that he consumes daily. This dependence upon a relative large quantity of air demands concern even though the concentration of pollutants is rather small. Such long term, low level exposure to polluted air is not yet fully understood, however, the disasters that have occurred during the past 50 years have been evaluated. The exact response of an individual to polluted air varies depending upon factors such as overall health,level of concentration, length of exposure, etc. However, the general health effects can be divided into three categories for future reference:

1. Acute illness; possible death.
2. Chronic disease, i.e., chronic bronchitis, emphysema, asthma. Research needed to understand relationships.
3. Annoyance, i.e., eye irritation, odors, nervous impairment.

Probably the most notable American episode occurred at Donora, Pennsylvania in 1948. The city with heavy industry (i.e., sulfuric acid plant, zinc production, and steel mill) suffered a three day thermal inversion. This trapping of pollution caused 6,000 people of the valley's population of 14,000 to be ill with eventually 20 deaths directly being attributed to the inversion. Finally, on the fourth day wind action cleared the sky bringing relief. Several other cases of urban disasters have occurred, i.e., London 1952; Birmingham, Alabama 1971; Miami Beach 1971; and it appears that these examples have served the purpose of forcing attention to the problem.

EFFECTS UPON PLANTS: In general, plant life is more sensitive to pollutants than animals since their cells are not protected by a mucous covering. The general categories of effects are listed as:

1. Acute - markings on leaves causing death of cells or whole tissues.
2. Chronic - gradual yellowing or discoloring of leaves.
3. Suppression - reduction of growth caused by reduced photosynthesis.

The total annual cost of plant damage in the United States has been estimated to be close to one billion dollars.

EFFECTS UPON MATERIALS: Gaseous acidic pollutants in general cause the damaging effects to materials. A few examples will help to illustrate the extent of damaging.

a. Steel corrodes two to four times faster in urban areas than in rural areas.

b. Hydrogen sulfide discolor lead-based paint and exposed metals - acid mists weaken nylon.

c. Stone facing eroded and darkened, i.e., New York Hilton required replacement in three and one-half years.

d. Ozone - a component of smog damages textiles and discolors dyes - rubber deteriorates.

Particles driven at high speed can cause a destructive erosion of building surfaces while increased cleaning costs related to particles settling on clothing must also be considered. The total annual cost associated with these material effects is most difficult to assess but it has been estimated at several billion dollars.

EFFECTS UPON THE ATMOSPHERE: This topic best considered by evaluating local effects separate from global issues. Pollution and other urban characteristics complexly affect the climate of the city. Every city is unique in the chemistry of its atmosphere and these differences may cause climatic variations. Wind is the basic parameter of urban climates, tall buildings increase friction and hence reduce the speed of moderate and strong winds, but increase turbulence during light wind situations.

Four factors contribute to the excessive heat of towns: Changes that buildings and road cause in the thermal characteristics of the surface; changes in airflow pattern due to reduced diffusion of heat; lower evaporation rates and heat loss; and heat added by man's activities.

Precipitation in cities is altered by three major factors: the presence of pollutants that serve as condensation nuclei; increased turbulence caused by buildings; and convective airflow becuase of higher temperature.

Example: La Porte, Indiana, is 30 miles east of the large complex of industries at Chicago. Since 1925 LaPorte has had a notable and anomalous increase in total precipitation, number of rainy days, number of thunderstorm days, and number of days with hail. After a careful assessment of all available climatological changes it has been concluded that the climatic changes are factual. The changes probably are a consequence of the outpouring of heat, nuclei and vapor from the distant steel plants and related industries.

In 1962, Landsberg compiled a detailed listing of climatic comparisons that show the effects of urban concentration in rural areas. Fuel burning and daily activities as well as the modified topography of a man made skyline have had direct and detremental effects.

FACTOR	Comparison with Rural Environs
Temperature	
Annual Mean	1.0 to 1.5°F higher
Winter Minima	2.0 to 3.0°F higher
Relative humidity	
Annual Mean	6% lower
Winter	2% lower
Summer	8% lower
Dust Particles	10 times more
Cloudiness	
Clouds	5 to 10% more
Fog, winter	100% more
Fog, summer	30% more
Radiation	
Total on horizontal surface	15 to 20% less
Ultraviolet, winter	30% less
Ultraviolet, summer	5% less
Wind Speed	
Annual mean	20% to 30% lower
Extreme gusts	10% to 20% lower
Calms	5% to 20% more
Precipitation	
Amounts	5 to 10% more
Days with 0.2 inch or less	10% more

Global

The extent of man's impact on the atmosphere is now global. There is now good evidence that air pollution is associated with certain changed in global climate. There is no proof, however, because of our inadequate understanding of the complexities of climate.

From the 1880's to the 1940's the average temperature of the world rose by at least 0.7°F. The warming may be a consequence of the increased CO_2 content of the atmosphere which, during the same period, rose about 11%. (Greenhouse effect)

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However, after 1940 the world began to cool off, and by 1960 had cooled about 30% of the previous rise, even though the CO_2 concentration continued to rise. It is suspect that the increased dustiness has caused the overriding cooling trend. Research is needed immediately to clarify the complex theory of global climatic change.

Air Pollution Control Methods

Air pollution is an issue which technology is capable of solving in terms of devices and techniques. The associated costs and lack of commitment related to these solutions, however, has prevented the necessary action. This problem is one which differs from place to place with little regard for man-made boundaries. Existing Governmental agencies at various levels are hard pressed to finance control programs. However, if one attacks the problem at the sources of emission it is manageable; i.e., furnaces, automobiles, etc. Such a philosophy has encouraged regional and eventual Federal approaches which are discussed in a later section.

PARTICLES: Control methods regarding particles depend primarily upon the size of the particle to be removed. Large particles (greater than 1 micron dia) will settle due to gravitational effects and gravitational settling chambers are used to provide time for gravity to act. If ~~is~~ the velocity of a fluid is reduced, the particles that can be carried in airborne suspension are of smaller and smaller size. In order to expedite the separation, cyclonic separators can be used to spin the polluted gas and utilize centrifugal forces to collect the particles at the rim. Another alternative is to spray water through the air mass and increase the weight of the particles by a wetting action. The resulting dirty water is then treated off line with the particles having been removed as small as 0.01 microns. Filters could be used to remove sizes down to 0.1 microns; and finally, electrostatic precipitators could be employed to remove particles. In the section dealing with suggested experiments a complete explanation of the principles of an electrostatic precipitator is discussed fully. Power plants are presently being built and proposed incorporating precipitators or combinations of devices, however, none of the above methods is easily adaptable to mobile sources such as the internal combustion engine.

GASES: The treatment of pollutant gases utilize the concepts of adsorption and chemical reactions. Scrubbing devices which spray water through the air mass enables soluble gas to be removed; i.e., SO_3 removed as a weak acidic solution. Adsorption uses an activated charcoal or silica gel like material to remove gases while devices such as catalytic mufflers are used to convert gas into harmless end products. In the case of the automobile, CO is converted to CO_2 and hydrocarbon vapors are converted to water and CO_2.

Governmental Programs of Control

Current legislation and governmental programs have been organized ar many levels and the following brief summaries give one some familiarity with the extent and direction of current efforts.

FEDERAL GOVERNMENTAL ACTIVITIES: The Air Quality Act of 1967 requires the Secretary of H.E.W. to report annually to the Congress regarding the progress in the area of prevention and control of air pollution. This annual report is an excellent summary of the overall comprehensive Federal effort and the following comments will briefly highlight the 1971 report.

The regional control machinery has been set up for 25 air quality control regions. Local State governmental agencies have begun to adopt sulfur oxides and particulate air quality standards that have been developed as a result of Federal sponsored studies. The National Air Pollution Control Administration (NAPCA) published the 1st criteria documents which dealt with sulfur oxides and particulate matter on February 11, 1969. In early 1970 the NAPCA published criteria for carbon monoxides, photochemical oxidants and hydrocarbons. In addition, criteria data for nitrogen oxides, lead, fluorides, and polynuclear organic compounds were released in 1971.

Federal research is presently attempting to identify and interpret health risk associated with the major pollutants, singly or in combination. Efforts to identify and quantify the economic and esthetic effects of air pollution are also being pursued.

Surveillance of air quality and data collection in conjunction with a computer national air data bank is maintained by over 200 stations across the nation.

Public hearings are held to involve local government agencies and citizens when violations of established air quality are reviewed. At this time the Federal agency (NAPCA) serves as the source of technical information. It has been the general policy of the Federal government to encourage and assist local level enforcement.

Research programs presently under grant include fuel desulfurization, new combustion processes, incineration techniques and the development of Rankine-cycle engines (steam) as alternatives to the traditional internal combustion engine.

Since it has been stated elsewhere, it will simply be mentioned here that the automotive emission guidelines were federally developed and expanded to trucks and diesel units in 1970.

NEW YORK CITY PROGRAMS OF AIR POLLUTION CONTROL: The City of New York has been studying and organizing data for almost 14 years. As a result of this effort, a daily Air Pollution Index is reported which indicates the levels of SO_2, CO, and smokeshade. A joint effort between New York and New Jersey has resulted in an air pollution alert-warning system which includes detailed reactions depending upon the degree and duration of air pollution. Such items as a gradual curtailing of incinerator burning and power generation reduction are included as well as total automobile banning.

In November 1966 the city entered a unique agreement to reduce air pollutants by specific amounts in a period of five years. The SO_2 was to be reduced by 1/3; the particulate matter was to be 1/2; and the CO level was to be reduced but a specific cutback was not stated in 1966. Local Law 14 (1966) restricted the use of coal and gave a timetable of sulfur content reduction from 2.2% to 1% by May 1971. Existing residual oil burners have been upgraded while an educational program for stationary engineers has been conducted to encourage proper techniques and equipment usage. Increased use of temperature controlled natural gas and central utility electric heat has also been promoted.

A program of cleaner waste disposal has included such actions as upgrading municipal incinerators, inspection of private units and burning of wastes 12 miles offshore.

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New York City's 38 monitoring stations have provided a wealth of urban data and organized it to the point of indicating plans of action while the relatively small enforcement staff has answered 53,000 complaints which resulted in 9,600 violations during an 18 month period. The magnitude of the city will demand even greater efforts than have been initiated by the initial 5 year plan.

AIR POLLUTION CONTROL (NASSAU COUNTY): As an example of local governmental control one can investigate the efforts being made in a major suburban community. Nassau County (Long Island) is located on the eastern boundaries of New York City. It is a densely populated region of approximately 1.9 million people. The major contributor of air pollution is the automobile which adds over 75% (by weight) of the air pollutants to the area air mass. The closeness to New York City results in direct air pollution interaction. Studies have shown that 30% of the time the winds are from the west and as such, Nassau lies subject to air pollution fallout from the city.

The county is not noted for heavy industry, but it does host a large light industry community. Housing is primarily single family units with only minor apartment house type facilities.

With this brief background it is possible to understand the specific county programs and goals.

Incinerators: County law requires all municipal (13) and private (3000) incinerators to provide adequate burning and discharge characteristic. Alterations are in effect which are to be completed by 1972.

Private incinerators will be closed down by January 1973 and new private incinerator construction has been prohibited as of January 1971.

Sulfur Dioxide Control: Fossil fuel burning is the prime source. In October 1969, the maximum allowable sulfur content was reduced from 2% to 1% - a further reduction to 0.37 is scheduled for 1971.

Industrial & Commercial Operations: Operating certificates are required by law and they are reviewed every three years. Air pollution control equipment must be installed and in good condition.

Automobile Controls: The county is relying upon federal legislation to answer the general problem. In the interim smoky cars and trucks were apprehended and corrections obtained for over 1,000 cases during 1969.

Complaint Investigation: 1,600 separate complaints were investigated in 1969.

Air Sampling: 18 sampling stations; 2 mobile labs aircraft emission studies in the Inwood area.

Future Goals and Landmarks of Air Pollution Control:

1967	County Law Adopted.
	Open burning banned.
1968	Voluntary changes from coal to oil.
1969	Sulfur in fuel down to 1%.
	Control of industrial and commercial plants implemented.
1970	County Law tightened.
	Study of aircraft emissions started.
1971	Federal controls on auto exhaust in effect.
	Sulfur in fuel down to 0.37%.
	Industrial and commercial plants to have emission control.
1972	Municipal incinerator control devices completed.
1973	Private incinerators phased out.
1975	Annual tons discharged per year @ 725,000 vs 1,160,000 tons in 1968.

Specific Issues

An Urban Problem and a Sample of Success

It appears that air pollution disasters that have already occurred have not really caused a reversal in the trend of urban air pollution episodes. However, examples of increased death rates related to sulfur oxide concentration have generated sufficient public alarm to force a reversal at least in the case of New York City.

Table 3

Examples of Acute Episodes of Air Pollution

Date	Location	Levels of SO_2	Effects
Dec.1-5, 1930	Meuse Valley, Belgium	Max. 9ppm (estimated)	63 died. Several hundred severe respiratory cases
Oct. 1948	Donora, Pa.	Greater than 0.4ppm daily average (estimated)	20 died. 43% affected to some degree. 10% severely affected
Dec. 1952	London	1.34ppm daily average (4500 micrograms per cubic meter for particulates)	4000 excess deaths
Dec. 1956	London	0.4ppm daily average (1200 micrograms per cubic meter for particulates)	400 excess deaths
Nov. 1953	New York City	0.86ppm Daily average	200 excess deaths
Nov. 1966	New York City	0.51ppm Daily average	168 excess deaths

Source (for Tables 3-6): Air Quality Criteris for Sulfur Oxides. The National Air Pollution Control Commission, U.S. Dept. of Health, Education & Welfare, January 1969.

Inspired by the now famous 1966 Thanksgiving Day episode that struck the Middle Atlantic urban region, New York developed a code which was to reduce the sulfur oxide levels by 50% in 5 years. The results of their effort will be discussed shortly, however, it is of benefit to briefly highlight the details of sulfur oxide's generation and effects.

Health oriented effects of sulfur oxide are only one of many that can be directly traced to their presence. Such additional effects as increased corrosion of metals, plant damage, reduced atmospheric visibility, weaken fabrics (i.e. cotton, rayon and nylon) and attacks upon building materials (i.e. limestone, marble, etc., are related to this pollutant. However, since the health issue is most critical, it is the only one considered in this section. In addition, the health disasters are usually directly correlated to excessive concentrations of sulfur dioxide that existed at the time.

Classifying specific harmful effects of atmospheric sulfur oxides to man is extremely difficult due to the large number of factors involved; i.e., general state of health, age, hygiene habits, etc. However, the National Air Pollution Control Administration has attempted to compile data in order to determine generally unacceptable levels which can be used as guide lines.

Table 4

Effects of Sulfur Oxides on Health

SO_2	Averaged Period	Effects That May Occur
0.25	24 hours	Increased mortality
0.21	24 hours	Symptoms increase in patients with chronic lung diseases
0.046	1 Year	School children suffer increased severity and frequency of respiratory disease
0.040	1 Year	Increased mortality from bronchitis and lung cancer

Source of sulfur oxides are varied. However, they include sea spray aerosols, volcanic activities, swamp gas (H_2S) and man-made combustion products. The hydrogen sulfide gas (rotten egg odor) results as a product of the bacterial reduction of organic matter. It rapidly oxidizes to form sulfur dioxide in the atmosphere.

Man became an active partner to nature in the discharge of sulfur compounds as a result of his fuel burning and the following table lists the various emission tonnages.

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Table 5

Annual World-Wide Emissions of Sulfur (tons)

Source	Quantity of Sulfur Emitted (millions of tons)
Pollutant sources of sulfur sioxide (man-made)	73
Hydrogen sulfide from biological processes on the continents	68
Hydrogen sulfide from biological processes in the oceans	30
Sea spray (mostly sulfate aerosols)	44
Total	215

Average concentrations of sulfur compounds in the atmosphere are approximately constant because sulfur is precipitated from the atmosphere as sulfate solution in rainwater. It is absorbed directly in gaseous form by the ocean and by plant vegetation. (Sulfur in the form of sulfur dioxide has an estimated residence time in the atmosphere of 4 to 5 days).

The following repeated table shows the major emissions that are considered as pollutants. Such bulk data must not be taken out of context by neglecting to mention the significance of local topography and meteorology, height of emission, population density and rate of emission. Mere weight of pollutants can also mislead since the level of SO_2 that is needed to cause harmful effects is relatively small.

Table 6

Emission of Five Major Air Pollutants in the United States by Source of Pollution (1966)

(Data in millions of tons per year)

Source	Sulfur Dioxide	Particulates	Oxides of Nitrogen	Hydrocarbons	Carbon Monoxide
Automobiles	1	1	6	12	66
Major Industries	9	6	2	4	2
Electric power generation	12	3	3	1	1
Space Heating (indoor heating)	3	1	1	1	2
Refuse disposal	1	1	1	1	1
Total	26	12	13	19	72

With an understanding of how SO_2 is generated the New York Control Program is understood by comparing the same pollutants on a local level that were emitted in 1966 and 1970. Table 7 shows the significant reduction in sulfur dioxide in the areas of heating and power generation, while it also shows the lack of progress associated with automotive pollutants.

The sulfur content of typical residual fuel oil used in New York area before 1964 averaged around 3%. In 1964 the administrative code limited the sulfur content to a maximum of 2.8%. Subsequently N.Y.C. Local Law 14 (May 1966) reduced the allowable content to 2.2% by May 1969 and to 2% by May 1971. Thereafter the limit would be reduced to 1%.

Reluctance of oil companies to develop the processing capability of low sulfur oil melted away when it was realized that the local governmental agency meant business. One can only guess at the results this example will have when the other urban centers begin to act as a consequence of New York's example.

Table 7

Emission of Five Major Air Pollutants
in New York City by Source of Pollution (1966 and 1970)
(Data in thousands of tons per year)
Numbers in parenthesis are 1970 values

Source	Sulfur Dioxide	Particulates	Oxides of Nitrogen	Hydro-Carbons	Carbon Monoxide
Transportation	20 (20)	10 (10)	51 (50)	189 (160)	1564 (1370)
Manufacturing	11 (9)	6 (5)	3 (3)	1 (1)	1 (1)
Electric Power Generation	323 (150)	13 (6)	102 (110)	2 (3)	1 (1)
Space Heating	530 (210)	29 (22)	127 (130)	7 (7)	20 (20)
Refuse Disposal	3 (3)	32 (26)	3 (3)	24 (18)	46 (35)
Evaporation of fuels and solvents	-	-	-	116 (115)	-
Total	890 (390)	90 (70)	290 (300)	340 (300)	1650 (1400)

Air Resource Commission - N.Y. City 1970 Report.

New York's success must be kept in context since the added cost of low sulfur fuel needs to be compared to the benefits. Such low-cost benefit analysis work suffers from subjective factors, however, the example still demonstrates it can be done.

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The Mechanics of a Thermal Inversion

Air pollution problems are aggravated when there is an inhibition of the normal dispersal processes of pollutants. Irregularities of the landscape may provide horizontal barriers to dispersal while a thermal inversion may act as a ceiling. Where the two conditions prevail, accumulation of pollutants results. The most potentially dangerous situation occurs in an industrial region situated in a basin or valley that is susceptible to thermal inversions.

Normal thermal behavior in the troposphere involves a decrease of temperature with height. A layer of air is characterized by a thermal inversion when its temperature increases with height. The means whereby a thermal inversion acts as a ceiling to pollutant dispersal is illustrated by considering the concept of atmospheric stability. Let us isolate a unit volume of air, an air parcel, very close to the Earth's surface. The pressure, the weight per unit area, of the atmosphere is greatest at the ground and decreases with height. Hence, initially the air parcel is imbedded in an environment of relatively high pressure. If the parcel is lifted, it is displaced into regions of steadily decreasing pressure. At this point it is assumed that the parcel does not mix with its environment; i.e., it retains its identity and there are no motions of the surrounding air which compensate for the displacement of the parcel. Because the pressure on the rising parcel decreases, its volume increases. This is what happens to a helium-filled balloon as it rises through the atmosphere. If there is no loss or gain of heat energy through the imaginary walls of the air parcel, the energy initially contained in the parcel at ground level must spread out to occupy an ever-increasing volume as the parcel rises. As the heat energy spreads out, the temperature drops. Hence, rising air cools. This cooling takes place at a constant rate of about 5.4°F/1,000 ft.

In a layer of air characterized by a thermal inversion, air warms with height. Thus, a parcel isolated in the layer and displaced upward will always be cooler and therefore, heavier than its environment. Even if the parcel of air is given an initial upward thrust, it will eventually return to its original position. An inversion is said to be a case of atmospheric stability. Thus, motion of air parcels through an inversion is prevented. An analogous stable system is a golf ball resting at the bottom of a bowl. Any displacement of the ball will be followed by a return to its original position under the influence of gravity. An inversion thus prevents vertical mixing of air and leads to accumulations of pollutant-bearing air parcels. Continued input into this stable layer results in dangerous concentrations of pollutants.

The Problem of Automotive Emissions

Presently over 100 million motor vehicles are operating on the nations' highways. It has been estimated that these units release each year approximately 60 million tons of carbon monoxide, 16 million tons of hydrocarbons and 7 million tons of nitrogen oxides. A typical average vehicle emits 1200 lbs of carbon monoxide, 320 lbs of hydrocarbons and 140 lbs of nitrogen dioxide each year.

In order to reverse the growing trend of increased levels of these pollutants in our cities, the Federal government passed the Clean Air Act which requires major reductions of these pollutants by 1975. The Federal action is an attempt to combat the problem at the sources and as such the relatively few major manufacturers of vehicles are subjected to annual inspections of their current line of products. Problem areas such as Los Angeles have also imposed guidelines above and beyond the Federal laws. The Federal government is also conducting research to develop new engine designs and better understanding of the exact manner of interaction between man and these pollutants.

Carbon monoxide is formed as a result of incomplete combustion of the air-fuel mixture. By allowing greater time for the combustion to take place, it is possible to reduce this emission; however, limitations exist regarding desired performance so that a compromise must be eventually reached. Retardation of the spark or the use of a clean air-fuel moistures has been implemented to improve the pollutional behavior of existing engine designs.

Hydrocarbon emissions result from inefficient fuel burning or a leak of fuel vapors. During the explosion within the cylinder, a partial quenching of the flame at the cooled cylinder walls prevents oxidation of the hydrocarbon fuel. Worm rings in the piston cylinder assembly serve as a source of leaked hydrocarbons (blow- by) from the chamber while vapors can also escape from the gas tank and carburetor unit. Presently blow-by emissions have been eliminated by a recycling of vapors from the crankcase to the carburetor while activated charcoal canisters have been used to collect and prevent gas tank vapor emissions. Exhaust pipe emissions of unburnt hydrocarbons are presently being attacked by various catalytic muffler devices which also have the ability to reduce carbon monoxide to carbon dioxide.

Efforts to minimize hydrocarbon and carbon monoxide emissions by completing the combustion results in higher cylinder temperatures. Associated with these increased temperatures has been the problem of increased emission of nitrogen oxides. Presently developed technology calls for an air injection of 10% cooled recycled exhaust gases to the carburetor. The resulting cooled combustion decreases the nitrogen oxide levels, however, at the expense of a loss in performance and decreased fuel economy. (Catalytic mufflers are now being researched which will convert nitrogen oxides back to nitrogen and oxygen). It is estimated that a developed system of catalytic muffler and exhaust recycle will cost approximately $200 per car. Most catalytic mufflers are fouled by leaded gasoline exhaust, therefore, unleaded fuel would be required.

Demands for high performance engines after World War II were met by designing engines with high compression ratios. Such compressions of the air-fuel mixture encourages ignition before the spark causing a vibration or knock and subsequent loss of performance. Lead compounds were added to gasoline as an economical means of preventing such premature and uncoordinated explosions rather than the more expensive refining methods of generating fuels with similar behavior.

A similar approach to emission control has been taken by DuPont which will not require the use of unleaded gasoline. (It is to be noted that DuPont is one of the two major suppliers of lead additives to the gasoline industry). DuPont has introduced and tested a total system which includes an exhaust manifold thermal reactor capable of completing the combustion of exhaust hydro-carbons and carbon monoxide without the use of a catalytic substance.

In order to control nitrogen oxides an exhaust gas recirculation is introduced which takes exhaust gas from the engine and returns a portion to the carburetor. This returned gas effectively dilutes the air-fuel mixture so that the formation of nitrogen oxide is reduced. Finally, exhaust cyclone traps are used to collect and remove particulate matter from the emission.

The results of testing and compliance with stated standards are very encouraging and follow. If such a system is utilized, Detroit will not need to modify the well entrenched capital investiment associated with the internal combustion engine. The results of the DuPont test in comparison with the Federal Standards are shown in Table 8.

Table 8

Total Exhaust Emission Control System

Exhaust Emission Standards & Goals
Emission Levels, Grams/Mile

Year	HC	CO	NO_x	Particulate Matter
1970	2.2	23.0		
1975	0.5	11.0	0.9	0.1
1980	0.25	4.7	0.4	0.03
		Results of DuPont System		
Car A	0.30	11.0	0.7	0.04
Car B	0.20	8.0	0.6	0.03
Car C	0.20	7.0	0.7	N.A.

Popular 4-door 1970 V-8 engines with automatic transmissions - 5% loss in fuel economy.

Since the automobile is accountable for 60% of this nations total air pollution ills and cause more than 85% of urban problems, it is understandable that the Federal government Senate Committee on Commerce (1969) held hearings on a "Search for a Low-Emission Vehicle." As a direct result of these hearings, the Committee overwhelmingly endorsed the use of a steam engine alternative to the internal combustion engine. The steam engine being an external combustion engine is capable of burning cheaper fuels in a more complete fashion resulting in emission characteristics that are quite impressive.

	Steam Car	Uncontrolled Internal Combustion Engine
Hydrocarbons	20 ppm	9000ppm
Carbon Monoxide	0.05%	3.5%
Nitrogen Oxides	40ppm	1500ppm
Lead	None	Depends on gas used.

The Rankine (steam engine) has the advantage of full power immediately (high torque at low speeds) and therefore does not need a transmission to accelerate. It also has a rapid start up (20 sec) which is a marked improvement over the well known Stanley Steamer. The risk of explosion during a crash has also been greatly reduced in comparison with a 20 gallon tank of typical present day fuel carried by automobiles.

Why then hasn't the switch over been made? First and foremost is the inertia of the existing automobile industry. The big three of Detroit (G.M., Ford, Chrysler) have seen no consumer demand generated that would warrant steam engine usage. Secondly, is the petroleum industry complex. Present refineries for high-octane fuels would need to be revamped in order to produce the needed low-grade kerosene. The costs of overhaul to the auto industry are almost prohibitive; therefore, it is likely that little beyond modifying the existing internal combustion engine will be done by them on a voluntary basis. This fact leads into the third and overlapping impediment to change which is the costs associated with entering the automobile market with an independent alternative. In order to produce the necessary volume of units to reach the economies of scale, the Senate Committee has suggested steps which would help in creating the market. The suggestions include:

a) Congress legislate to require procurement of low-emission vehicles.

b) State and local levels of government should do likewise.

c) The Department of Transportation should finance demonstration projects of steam engine cars.

d) The Department of Health, Education and Welfare should devote greater portions of research funds into this area.

e) Mass transit operations that require fleets of vehicles should be encouraged to procure low emission units.

It remains to be seen, however, just how the give and take arena of our government and industrial complex will reach a solution.

Student Experiment Sample

Efficiency of an Electrostatic Precipitator

Object: The object of this experiment is to qualitatively illustrate one of the typical air pollution control devices.

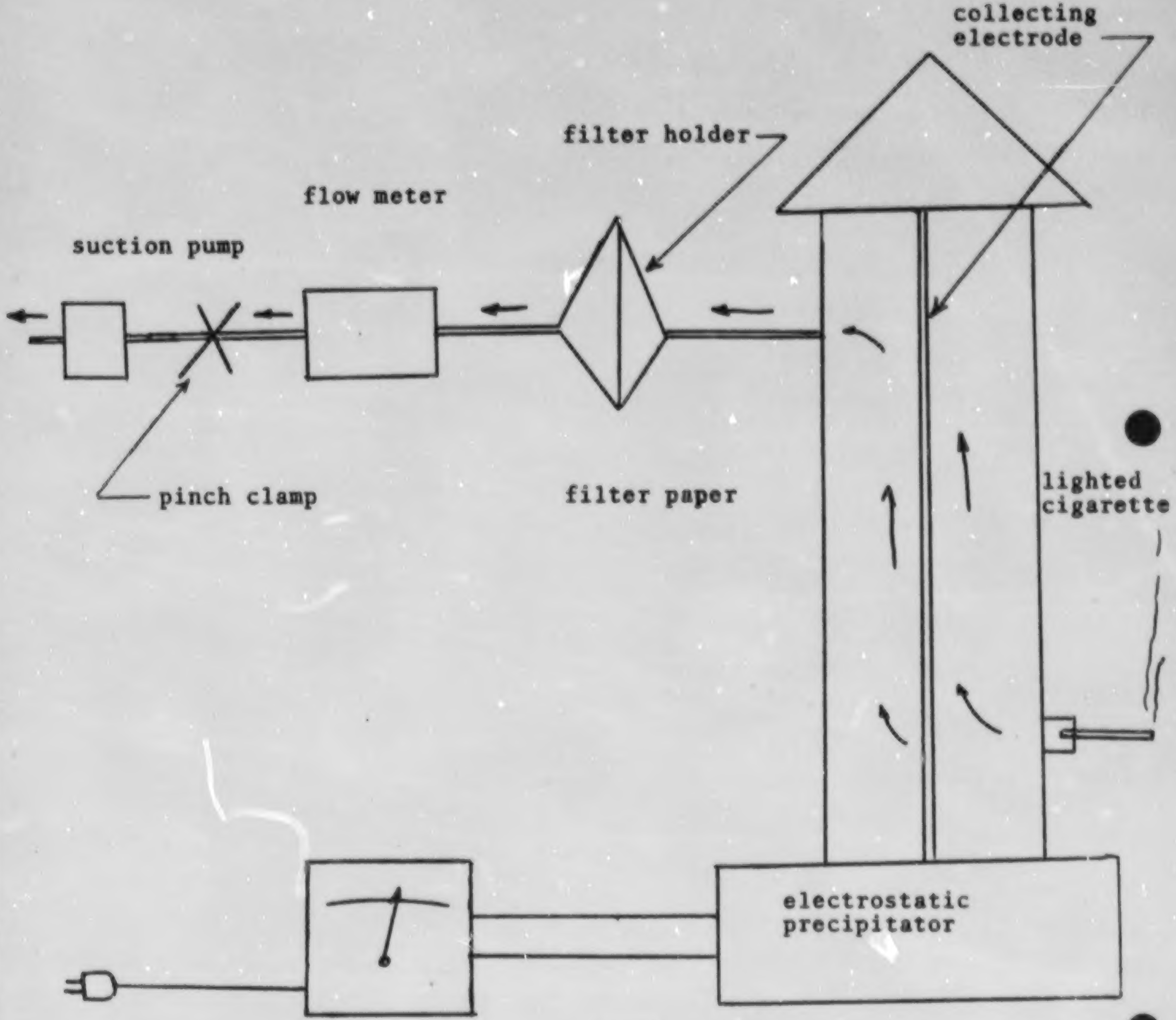
Theory: An electrostatic precipitator is a device which utilizes a high voltage difference between two electrodes in order to ionize the air between the electrodes. This ionized air in turn charges the particles in the air and they can then be drawn to the oppositely charged electrode. (The ions attach themselves to the particles in order to "give" these particles a charge). Once the particles have been transported to the collection electrode they must be removed periodically in order to prevent reetrainment and also to allow the electrical forces of the electrode to perform at full capacity.

Industrial electrostatic precipitators are usually a single stage, rod and tube type wherein the gases to be cleaned are passed through a high intensity, direct current field. They are frequently employed in metal processing industries to collect the fine metallic oxide fumes; in the public utility type furnace systems for removing fly ash; and by the carbon black industry to prevent loss as well as pollution. They are capable of handling gases which are hot (up to 1100°F) or cold, wet, or dry. In 1969 alone, almost one billion cubic feet per minute or industrial gases were cleaned with such units.

Equipment:

1. Eduquip Electrostatic Precipitator.
2. Ten feet of plastic tubing.
3. 6 to 12 volt D.C. power source.
4. Eduquip smoke generator
5. A flow meter (0-5 liters per minute).
6. Filter holder assembly including filter paper.
7. A suction source capable of drawing 3 liters per minute (pump or aspirator).
8. Stopwatch
9. Pinch clamp
10. Analytical balance capable of reading 0.1 milligram.

Experimental Procedure:


collecting
electrode
filter holder
flow meter
suction pump
pinch clamp
filter paper
lighted
cigarette
electrostatic
precipitator

0-12 volt DC Power Supply (2 amp min.)

Dry 6 pieces of filter paper in a desiccator overnight. Label them 1 thru 6 with a pencil on the smooth downstream side. Weigh each filter on an analytical balance to the nearest 0.1 milligram. Record these weights for the six filters and insert #1 into the filter holder. Start the suction pump and adjust it so that approximately 1.5 liters per minute is obtained as a reading on the flow meter. Insert a smoke source at the inlet to the precipitator. Using a stopwatch and leaving the precipitator deenergized allow smoke to be generated through the precipitator and filter for exactly 2 minutes. A pinch clamp can be used for an off-on switch on the line connecting the suction pump to the flow meter. Remove filter #1 from the holder and place it in a desiccator.

Clean the entire precipitator and filter holder with tissue paper. Place filter #2 in the holder and repeat the experiment with the electrostatic precipitator energized at 6 volts. Open the pinch clamp and activate for 2 minutes. Make a series of such runs with a cleaned unit at voltages of 8, 10, and 12 volts. Finally, using filter number 6, rerun the experiment at zero volts.

After 24 hours in a desiccator weigh the filters. The net gain on the filter divided by the product of the sampling rate and sampling time will yield the concentration of smoke which passed through the electrostatic field in micrograms per cubic meter.

Sample Calculation:

(a) Filter #1 net weight gain = final wt - initial wt
0.0103 gm = 0.9103 gm - 0.900 gm
(b) Filter #2 net wr. = 0.9330 gm - 0.9321
= 0.0009 gm

$$\text{Collection efficiency} = \frac{\text{filter \#1 gain} - \text{filter \#2 gain}}{\text{filter \#1 gain}}$$

$$\text{Eff.} = \frac{0.0103 - 0.0009}{0.0103} \times 100 = 91.2\%$$

Questions & Analysis:

1. Compute and compare the results of all six runs.
2. Evaluate the effect of varying voltage upon collection efficiency.
3. Why isn't the device used to clean the exhaust of an automobile.

AIR POLLUTION DEMONSTRATION

High Volume Particulate Sampling (Indoors)

Introduction:

One of the major indices of air pollution is the quantity of particulate matter in each cubic meter of air in the environment. A standard technique for determining the mass of particulate material in the atmosphere is to draw the air through a preweighed high efficiency (small pore size) filter at a known volumetric flow rate. The filter collects all the particulate matter in the air which passes through it. It may then be reweighed to determine its net gain. The Public Health Services, both State and Federal, use this technique as the accepted standard for particulate concentration determination. This experiment uses a high pressure blower to draw particulate laden air through a filter. It does not depend on the settling out of particles and therefore samples a greater fraction of matter. It is also very accurate but only for a mass determination. Particle count and size determinations are impossible.

The High Volume Sampler is a device which draws upwards of 1500 liters per minute of ambient air through a piece of high efficiency fiber glass filter paper. This technique enables the investigator to sample a large quantity of air in a relatively short period of time. Very noticeable graying of the filter paper is evident within 30 minutes. Each "Hi Vol" comes with its own manometer which is connected to a tap at the outlet. The units are all factory calibrated and all the user need do is read the pressure differential on the manometer and compare it to the graph to determine the volumetric flow rate.

Equipment:

1. The High Volume Sampler
2. 1 box of high efficiency filter sheets
3. A balance capable of weighing to 1.0 milligram.

Procedure:

Release the clasp on the High Volume Sampler weather cover. Raise the gasketed frame by releasing its clasp. Desiccate a piece of filter paper for several hours. Put a number on the backside (smooth side) of the paper in pencil. Weigh the filter on an analytical balance to the nearest milligram. Record this weight.

Place a piece of filter paper over the screened backer with the rough side up. Secure the gasketed frame onto the filter paper so as to insure a leak tight seal around the edge. Close the weather cover and latch it. Place the High Volume Sampler in a corner of the classroom or in the hallway. It has been acoustically insulated to minimize the external noise level.

Operate the High Volume Sampler for four hours. Record the initial and final flow rates by reading the manometer with a clean piece of filter paper in place and the unit operating. Compare this reading to the graph supplied with the unit and record the flow rate. Repeat this step after the unit has operated for four hours. Use the average flow rate in your calculations.

After sampling for a four hour period remove the filter paper, put a new filter in and place the used piece of paper carefully into a desiccator. Weigh the piece of filter paper after it has been desiccated for several hours to find the net gain of collected particulate material.

Express your results in micrograms of material collected per cubic meter of air sampled.

Sample Calculation:

A desiccated filter had an initial weight of 3.300 grams. After sampling in the High Volume Sampler for four hours, it was desiccated and reweighed. The final weight was 3.600 grams. The initial flow rate was 1,700 liters per minute and the final flow rate was 1,300 liters per minute. Calculate the concentration of particulate matter in the sampled atmosphere in micrograms per cubic meter (g/m^3).

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final filter weight - initial filter weight = net gain (grams)

$$3.600\ \text{gm} - 3.300\ \text{gm} = .300\ \text{gm}$$

average flow rate = (1700 lpm - 1300 lpm)/2 = 1500 liters per minute

$$\text{concentration} = \frac{\text{net gain of particular matter}}{(\text{average flow rate})(\text{sampling time})}$$

$$\text{concentration} = \frac{(.300\ \text{gm})(10^{6}\ \mu\text{g}/\text{gm})}{\left(1500\ \frac{\text{liter}}{\text{min}}\right)\left(\frac{10^{3}\ \text{cm}^{3}}{\text{liter}}\right)\left(\frac{1\ \text{m}^{3}}{10^{6}\ \text{cm}^{3}}\right)\left(4\ \text{hr} \times 60\ \frac{\text{min}}{\text{hr}}\right)}$$

$$833\ \frac{\mu\text{g}}{\text{m}^{3}}$$

Comments and Discussion

Particulate Fallout Sampling

Background:

In addition to pollutant gases, large quantities of finely divided particles are emitted into the air daily as a result of human and natural activities. For purposes of classification, dust can be considered as soil particles, fabric fibers (lint), etc., while the term soot is usually defined as finely divided carbon particles resulting from improper combustion practices. It has been found that the particulate matter deposited upon a square foot of urban ground surface may well exceed a pound per year; therefore, sampling of such material deposited is related to a major urban pollutant.

A complete analysis of particulate fallout as a result of gravitational settling would include a counting and sizing of these finely devided samples. In this experiment we are interested in obtaining a relative density of particles deposited per unit time and some appreciation of the average size of the particles caught.

Aerosol mist sprays form very small droplets of liquid "particles"; however, our experimental procedures will not allow a sampling of such liquid particles.

Equipment:

1. 6-1" x 3" glass slides
2. immersion oil
3. cardboard sheets
4. single edge razor blades
5. graph paper
6. tape
7, metric scale (M.M.)

Procedure:

1. Mark your glass slides #1, #2, #3, etc., on the frosted end of the slide.
2. Prepare the glass slide holder from the cardboard provided as shown in class.
3. Place the glass slides in the holders.
4. Prepare the slides with immersion oil making sure that the slide is free of dust by wiping with cloth provided.
5. Place each prepared slide in some convenient location* exposed to the environment which you are interested in. After three hours remove your sample and cover it so that no more particulate material will collect upon it. (A convenient method is to stack the slide holders one upon another, each one protecting the one below it).

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*At least 4 feet above ground and not too close to walls.

6. The following lab period bring your samples in for inspection under the microscope projector.
7. Project and mark a test area on the graph paper indicating the relative size shown.
8. Place your test slide in the projector and count the particles.
9. Using a suitable scale, attempt to indicate the typical particle size.

Particle Counting Technique:

1. When counting particles under a projectional microscope, count one row of particles from the upper left hand corner to the upper right of the square. (The technique is similar to the operation of a typewriter).
2. Index down and move back to the left hand side of the square.
3. Count another row of particles once again moving from left to right until you reach the right hand edge of the square.
4. Repeat steps 2 and 3 until you have reached the bottom line of the square.

This method of counting particles minimizes counting a single particle more than once as well as minimizing the number of particles not counted at all.

Analysis:

Analyze your data a provided for in procedure #8, and assign a number to each slide for its degree of "pollutedness" (number 10 being the dirtiest and number 1 being the cleanest). Make a map of Long Island and put a star on the map where each slide was positioned (use the entire class's data). Cany any conclusions be drawn about any areas or communities from this data? Try to correlate wind direction with pollution. Is there any known major source of pollution in our near your town? Try to correlate pollution intensity with the distance from its source. The source may be a power generating station, an incinerator or an industrial factory.

Air Pollution References

Articles: The Control of Air Pollution
A. J. Haagen-Smit
Scientific American Jan. 1964

Air Pollution and Public Health
Walsh McDermott
Scientific American Oct. 1961

What Unleaded Gasoline Will Mean
Harvey Ardman
The American Legion Magazine Feb. 1971

Air Pollution From Motor Vehicles
Ralph Larsen
Annal of the N.Y. Academy of Sciences
Aug. 1966, Vol. 136 Art. 12

How Clean a Car?
John B. Heywood
Technology Review June 1971

Air Pollution Surveillance Systems
G. Morgan, G. Oyolins, & E. Tabor
Science Oct. 1970

Global Environmental Monitoring
George Robinson
Technology Review May 1971

Air Pollution in Perspective
(Four Part Series) by Edward Rubin
Technology Tutor 1970-71

The Global Circulation of Atmospheric Pollutants
Reginold Newell
Scientific American Jan. 1971

Pollution Causes, Costs, Controls
C & EN June 9, 1969

MAN'S IMPACT ON ENVIRONMENT (Reader), Thomas Detwyler
McGraw-Hill 1971.

Includes the Following Articles:

Air Conservation and the Kinds of Air Pollutants
Air Conservation Commission

Sources of Air Pollution
U. S. Department of H.E.W.

Meteorology of Air Pollution
Donald Pack

Geographical Aspects of Air Pollution
P. Leighton

Climate of the City
James Peterson

The LaPorte Weather Anomaly - Fact or Fiction
Stanley Changnon

All Other Factors Being Constant - Theories of
Global Climatic Changes
Reid Byrson

Damage to Forest from Air Pollution
George Hepting

Books:

Air Pollution
Richard Scorer
Commonwealth & International Library of Science,
Technology, Engineering and Liberal Studies 1968.

Air and Water Pollution
Gerald Leinwand
Washington Square Press 1969

Cleaning our Environment
American Chemical Society 1969

You and Technology
Nickander Damaskos
PMC College 1969

Technological Injury
Edited by J. Rose
Gordon & Breach Science Publishers

Ecological Crisis
G. Love and R. Love
Harcourt, Brace, Jovanovich, Inc.
New York 1970

Patient Earth
John Harte & Robert Socolow
Holt Rinehart & Winston, Inc.
New York 1971

Protecting Our Environment
Edited by Grant McClellan
H.W. Wilson Co.
New York 1970

Our World in Peril: An Environmental Review
Edited by S. Novick and D. Cottrell
Fawcett Publications, Inc.
Greenwich, Conn. 1971

The Following paperback will be used as a reader during the 1971-72 academic year.

Our World in Peril: An Environmental Review
Edited by S. Novick & D. Cottrell
Fawcett Publications.

Table of Contents includes the following articles on air pollution:

Taming the Weather by Frederick Sargent, II.

The Wind from Dugway, by V. Brodine, P. Gaspar, and A. J. Pallmann. Sheep-kill.

More Letters in the Wind by R. Risebrough and V. Brodine. PCB.

The Tailpipe Problem by John Macinko.

Not a Question of Size by W. X. Craig. Pollutants from Automobile Exhaust.

Asbestos by I. J. Selikoff.

On Breathing Sulfur Dioxide by Carol Collier.

Those Airborne Chemicals by J. G. Meyer

Leaf Burning: An Economic Case Study by R. E. Kohn.

The Windup Car by Kurt Hohenemser and J. McCaull. Flywheel power.

Reports:

A Total Exhaust Emission Control System
E. N. Cantwell (Sept. 1970)
c/o Petroleum Laboratory
E. I. duPont de Nemours & Co. (Inc.)
Wilmington, Delaware

Approaching the Clean Air
The City of New York, Department of Air Resources
51 Astor Place
New York, NY 10003 (Jan. 1969)

Air Pollution Control in Nassau County
Bureau of Air Pollution Control
Nassau County Department of Health
240 Old Country Road
Mineola, NY 11501

Air Pollutants from Internal Combustion Engines
by R.W. Hurn (AIAA Paper)
Technical Information Service
750 Third Ave.
New York, NY 10017

Determining Air Pollutant Emissions from Transportation
Systems by J. A. Kurtzweg & D. W. Weig
U. S. Department of Health, Education & Welfare
Public Health Service
National Air Pollution Control Administration
411 West Chapel Hill Street

Air Pollution Injury to Vegetation
U.S. Department of H.E.W.
Public Health Service
Environmental Health Service
National Air Pollution Control Administration
Raleigh, North Carolina

Progress in the Prevention and Control of Air Pollution
3rd Report of Sec. of H.E.W. to Congress
March 1970
U.S. Government Printing Office
Superintendent of Documents
Washington, D.C. 20402

A Guide to the Selection of Air Pollution
Control Equipment by J.P. Tomany
U O P Air Correction Division
Tokeneke Road
Darien, Conn. 06820

Laboratory References:

An Atmosphere in Crisis
Educational Modules Inc.
(Wards Catalog) 1970

Scientific Experiments in Environmental Pollution
by E. C. Weaver
Holt, Rinehart & Winston, Inc.
New York 1968

Eduquip Air Pollution Study Program Manual
Eduquip Inc.
1220 Adams St.
Boston, Massachusetts 02124

Air Pollution (paperback)
Addison Wesley Publishing Co.
Reading, Massachusetts

Films on Air Pollution

(A) Source: National Medical Audiovisual Center
Station K
Atlanta, Georgia 30324

1. The Poisoned Air (CBS Documentary)
   50 minutes/color/no fee/ order no. M-1418-X.

2. Air of Disaster (NBC Documentary)
   50 minutes/color/no fee/order no. M-1419-X.
   General Survey of National Problem.

(B) Source: McGraw-Hill Film Rental Office
330 W 42 St.
New York, NY 10036

1. Air Pollution:Take A Deadly Breath (ABC Documentary)
   54 min/color/$40 rental/Code No. 656125,
   Parts I, II, III.
   General Survey of National Problem.

2. Autos and All That Traffic
   25 min/color/$18 rental/Code No. 648019
   All Aspects included with air pollution effects as well as new engines being developed to meet the issue.

3. The First Mile Up
   28 min/black & white/$14 rental/Code No. 672320
   Detroit River Regional Approach to the problem of air pollution.

(c) Source: Florida State University
Media Center
Tallahassee, Florida 32306

1. Beware The Wind
   22 min/color $7 rental
   Shows sources of air pollution; effects on human plants and property; available technology is illustrated.

2. Problems of Conservation-Air
   15 min/color/rental $5.95
   Impact of industrial revolution in accelerating air pollution concentrations is highlighted.

(d) Source: Tuberculosis - Respiratory Disease Assoc.
of Nassau-Suffolk, Inc.
1432 Old Northern Boulevard
Roslyn, NY 11576

1. Battle to Breathe
   25 min/color/free
   Three actual case histories of emphysema are illustrated.

2. Human Body - The Respiratory System
   13 1/2 min/color/free
   film locates and describes respiratory system organs.

3. Life and Breath
   15 min/color/free
   Detection, examination and treatment of emphysema is illustrated.

4. The Runaround
   17 1/2 min/color/free
   Saterical tale of seeking out the source of air pollution climaxed by a plea from Senator Muskie.

5. Anatomy of a Disease
   15 min/color/free
   Clinical experiences explaining tuberculosis.

SOLID WASTE DISPOSAL

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PREFACE

The following material represents the grave magnitude of the solid waste problem in the United States and the current efforts to deal with the problem of solid waste disposal as of the time the material was collected. It should provide the factual background material necessary for any general discussion of the problem.

It should be recognized that with the passage of time, the magnitude of the problem will increase and, therefore, the efforts to deal with it will and should change. Many of the efforts reviewed in this report are in an experimental state. Some will prove promising and will be expanded, others will prove unsuccessful and will be discarded.

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I. OBJECTIVES

A. To familiarize the student with the growing magnitude and changing nature of the solid waste generation problem.

B. To familiarize the student with the various disposal methods, their limitations and the current effort to develop improved methods.

C. To emphasize to the student the current non-use of satisfactory techniques that are available and the dire need for a systematic effort for improvement by all levels of government and for an informed citizenry.

II. BACKGROUND

A. Solid Waste Generation (References 1,2)

1. Generators

An estimated 900 million pounds of solid wastes of all types are produced in the United States every day. What to do with these solid wastes, how to dispose of them without needlessly endangering public health and welfare, and how to recover and reuse valuable materials now "thrown away" are among the most challenging and perplexing of current national problems.

Solid wastes are being generated on an industrial-society scale but are being disposed of by methods from the horse-and-buggy days. Although some $3 billion of public money are spent annually in the

United States to collect and dispose of solid waste, the collection and disposal practices in common usage are but little improved over those a quarter century ago. Much of the blame must be attributed to the very nature and origin of the problem: Waste disposal has historically been relegated to the lowest levels of responsiblility. Thus, a major effort must be directed toward applying the technology now available and finding better ways to dispose of solid wastes. Above all, the techniques of system analysis must be applied. We should be spending at least $100 million a year on research toward better methods, yet we are currently spending less than $5 million nationally.

In addition to the increasing total, the composition of solid waste is changing. The biggest increase is in low density combustible rubbish, primarily paper and plastic. Small reductions are continuing to occur in the heavier refuse classes of garbage and ashes. Moisture content is decreasing. This has a direct bearing on disposal methods; some method of volume reduction must be used to conserve land areas for long term refuse disposal.

2. Definition of Waste

One of the first and most perplexing problems confronting a newcomer to the field of refuse collection and disposal is the vocabulary of the field. It is common for a city of use one of the many synonyms such as "garbage," "rubbish," or "refuse," to mean all the materials it collects and disposes of. Adding to the confusion in terminology is the wide variation in refuse collection practices of different cities. It appears essential, therefore, to define the words and terms used to identify different classes of refuse and to state what materials make up each class.

Waste:

The word waste refers to useless, unused, or discarded materials. Waste includes solids, liquids, and gases. The gases are principally industrial fumes and smoke; the liquids consist mainly of sewage and the fluid part of industrial wastes; the solids are classified as refuse. It is difficult to classify municipal wastes or to state absolutely the kinds of material that consitute the part called refuse. Part of the solid waste material produced in a city, particularly particles of garbage and rubbish, finds its way to the sewers and is disposed of with the liquid sewage wastes. Some semiliquid food wastes are collected as refuse.

Solid Waste: (refuse)

The term refuse refers to solid waste and the two are used more or less synonymously. Because solid waste is somewhat more descriptive and therefore less subject to misinterpretation it is being used more and is supplanting the term refuse.

Garbage, Rubbish, Trash, Litter, Junk:

Garbage is food waste that will decompose. Rubbish and trash include combustibles such as paper, wood, yard trimmings, and boxes, and noncombustibles such as metal, glass and dirt. Litter is any piece of discarded solid waste which is exposed and uncontrolled. Junk refers to anything currently valueless.

3. Classification of Solid Waste

The components of solid waste can be classified in several different ways. The point of origin is important in solving some problems, so that classifying as domestic, institutional, commercial, industrial, street, demolition, or construction is useful. For other problems, the point of origin is not as important as the nature of the material, and classification may be made on the basis of organic or inorganic, combustible or non-combustible, putrescible or nonputrescible. One of the most useful classifications is based on the kinds of materials: garbage, rubbish, ashes, street refuse, dead animals, abandoned automobiles, and hazardous and special waste. Table 1 groups solid waste materials by kind and composition and indicates in a general way the source.

a. Residential Waste contains a great variety of manufactured and natural products discarded by households. Accurate data about the composition of residential wastes are not available. However, the following is an estimated yearly average composition and percentage breakdown, by weight, (Reference 2)

Table 2

COMPOSITION OF RESIDENTIAL WASTES

Type	Weight-Percentage of Total Wastes
Paper	60.0%
Food	8.5
Glass and Ceramic	8.0
Metallic	8.0
Plants and Grass	6.5
Plastic	3.5
Furniture and Boxes	1.5
Construction	1.0
Textiles	0.5
Dirt and Vacuum Cleaner Catch	0.5
Rubber	0.4
Leather	0.4
Household and Garden Chemicals	0.4
Paints, Oils, and Varnishes	0.3
Miscellaneous	0.5

TABLE I
GENERAL CLASSIFICATION OF SOLID WASTES MATERIALS

Garbage		Wastes from the preparation, cooking, and serving of food Market refuse, waste from the handling, storage, and sale of produce and meats	From households, institutions, and commercial concerns such as: hotels, stores, restaurants, markets, etc.
Rubbish	Combustible (primarily organic)	Paper, cardboard, cartons Wood, boxes, excelsior Plastics Rags, cloth, bedding Leather, rubber Grass, leaves, yard trimmings	
	Noncombustible (primarily inorganic)	Metals, tin cans, metal foils Dirt Stones, bricks, ceramics, crockery Glass, bottles Other mineral refuse	
Ashes		Residue from fires used for cooking and for heating buildings, cinders	
Bulky wastes		Large auto parts, tires Stoves, refrigerators, other large appliances Furniture, large crates Trees, branches, palm fronds, stumps, flotage	From streets, sidewalks, alleys, vacant lots, etc.
Street refuse		Street sweepings, dirt Leaves Catch basin dirt Contents of litter receptacles	
Dead animals		Small animals: cats, dogs, poultry, etc. Large animals: horses, cows, etc.	
Abandoned vehicles		Automobiles, trucks	
Construction & demolition wastes		Lumber, roofing, and sheathing scraps Rubble, broken concrete, plaster, etc. Conduit, pipe, wire, insulation, etc.	
Industrial refuse		Solid wastes resulting from industrial processes and manufacturing operations, such as food-processing wastes, boiler house cinders, wood, plastic, and metal scraps and shavings, etc.	From factories, power plants, etc.
Special wastes		Hazardous wastes: pathlogical wastes, explosives, radioactive materials Security wastes: confidential documents, negotiable papers, etc.	Households, hospitals, institutions, stores, industry, etc.
Animal and agricultural wastes		Manures, crop residues	Farms, feed lots
Sewage treatment residues		Coarse screenings, grit, septic tank sludge, dewatered sludge	Sewage treatment plants, septic tanks

Source: Adapted from American Public Works Association, *Refuse Collection Practice*, 1966, p. 15.

It should be emphasized that the values given are only estimates and that composition vary with region, climate, and season.

b. Municipal Waste generally is composed of the same type of material as residential waste. However, these wastes contain an appreciably higher amount of oversized items such as abandoned cars, wooden logs, and unusual wastes such as dead animals. They also might include incinerator ashes, sludge from sewage treatment plants and dirt from street sweepings. Loads of wastes collected from parks sometimes contain garden wastes exclusively.

c. Commercial Wastes originate mainly in offices, stores, theaters, markets, etc. They usually contain large amounts of packaging material and food discards. (Hospitals and clinics also discard these types of wastes, however, they also generate hazardous chemical and pathological wastes which can generate health hazards.)

d. Industrial Solid Waste includes a large variety of organic and inorganic wastes. A brief description of specific waste types associated with a few industries are given below. (Reference 2)

Table 3

INDUSTRIAL WASTES

Industry	Waste Types
Paper	Sawdust, dust from rag stock, lime sludge, black carbon residue, paper rejects.
Fruit and Vegetable	Scraps of fruit and vegetable, seeds, cobs, oils, processing chemicals
Meat and Poultry	Flesh, entrails, hair, feathers, fat, bones, blood, grease
Dairy	Butterfat, milk solids, ash, acids, discarded mile and cheese
Glass and Ceramics	Broken ceramics, glass, sludges, dust, chemical, abrasives
Metallurgical	Emulsified cleaners, machine oils, oily sludge, borings and trimmings, toxic chemicals
Heavy metals	Slag, metallic dust
Plastics	Scraps from mouldings and extrusion, rejects, chemicals
Textiles	Textile fibers, rags, processing chemicals, detergents
Construction	Sand, cement, brick, masonry, metal, ceramics, plastic, glass
Chemical	Organic and inorganic chemicals, rejects of synthetic products, also can contain toxic, explosive, and radioactive waste
Lumber and Furniture	Sawdust, woodchips, abrasives, oily rags, upholstery materials, paints, varnishes, wood scraps

e. Agricultural Wastes in addition to products similar to municipal wastes contain large proportions of organic wastes from field and seed crops, vegetable crops and prunings. They also contain manure, and dead animals.

4. Composition

The composition of wastes and, therefore, the type source has a great effect on satisfactory collection and disposal techniques. Table 4 indicates average solid waste collected in the U.S.A. Agricultural wastes are excluded and municipal wastes are divided into (1) demolition and construction and (2) street and alley (Reference 3)

Table 4

AVERAGE SOLID WASTE COLLECTED, POUNDS PER PERSON PER DAY

Solid Waste	Urban	Rural	National
Household	1.26	0.72	1.12
Commercial	0.46	0.11	0.38
Combined	2.63	2.60	2.63
Industrial	0.65	0.37	0.59
Demolition and Construction	0.23	0.02	0.18
Street and Alley	0.11	0.03	0.09
Miscellaneous	0.38	0.08	0.31
	5.72	3.93	5.32

Table 5 gives both the physical and chemical composition for combined household, commercial and municipal waste collected as reported by one investigator. (Reference 4)

Table 5

SAMPLE COMBINED REFUSE COMPOSITION - U.S. EAST COAST

Weight Percent

Physical		Chemical	
Cardboard	7%	Moisture	28.0%
Newspaper	14	Carbon	25.0
Miscellaneous Paper	25	Hydrogen	3.3
Plastic Film	2	Oxygen	21.1
Leather, Molded Plastics, Rubber	2	Nitrogen	0.5
		Sulfur	0.1
Garbage	12	Glass Ceramics, etc.	9.3
Grass and Dirt	10	Metals	7.2
Textiles	3	Ash, other inerts	5.5
Wood	7		
Glass, Ceramics, Stones	10		
Metallics	8		
	100%		100.0%

a. Increasing Plastic Content in Total Composition

The dramatic increase in the volume of domestic refuse is, to a significant extent, caused by an increase in packaging waste. This volume would be even larger and the weight would be considerably greater if plastics had not replaced a portion of the glass during the past several years. Even so, the current percentage by weight of plastic wastes collected is less than 2% and is not expected to exceed 3% by 1980.

The increasing amount of plastic wastes, coupled with the decreasing amount of ashes resulting from the decreasing dependence of private housing on solid fuel, result in the decreased Btu content of solid waste and require properly designed and operated modern incinerators to provide suitable incineration. In addition, evidence is rapidly accumulating that a significant portion of the theoretical hydrochloric acid formed in the oxidation of polyvinyl chloride polymers (pvc) does not appear in the gases at the top of the stack and thus is not a serious air pollution hazard.

Plastic wastes in sanitary landfill or compost operations, especially when properly comminuted, act as inert materials having no long-term adverse effects.

B. Disposal Techniques

1. Objective

The aim of solid waste disposal processes is to reduce primarily the volume and secondarily the weight of refuse, so that it can be disposed of more readily, and to convert it to a less offensive form. Currently about 90% of the wastes go to some 12,000 land disposal sites, of which only about 6% are considered adequate sanitary landfills. About 8% is disposed of in some 300 municipal incinerators, of which only about 30% have adequate air pollution controls. The remaining 2% is disposed of by hog feeding, composting, etc.

The selection of best methods of refuse disposal is of utmost importance. Systematic consideration must be given to many factors and a number of questions answered before a decision can be made: (Reference 5)

1. What methods are technically feasible, and what are the limitations of each?
2. Do local conditions make some methods particularly suitable or unsuitable?
3. What factors, such as good public health features or fewer potential nuisances, favor one method over another?
4. Will weather, mechanical failure, or other circumstances interrupt procedures and with what results?
5. What are the costs of the various methods; how do they vary and with what factors?
6. What effect do collection procedures have on cost of disposal?
7. What effect will the disposal method have on the cost of collecting?
8. What methods can be adapated economically to changing conditions?
9. Will salvage or reclamation pay part of the disposal cost?
10. What elements in each method are likely to gain public support or meet with antagonism?

2. Techniques in Use

a. Sanitary Landfills (References 5,6,7,8,9)

(1) General description of sanitary landfill

A sanitary landfill has been defined by the Committee on Sanitary Landfill Practice of the Sanitary Engineering Division of Civil Engineers as "A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical volume, and cover it with a layer of earth at the conclusion of each day's operation or at such frequent intervals as may be necessary."

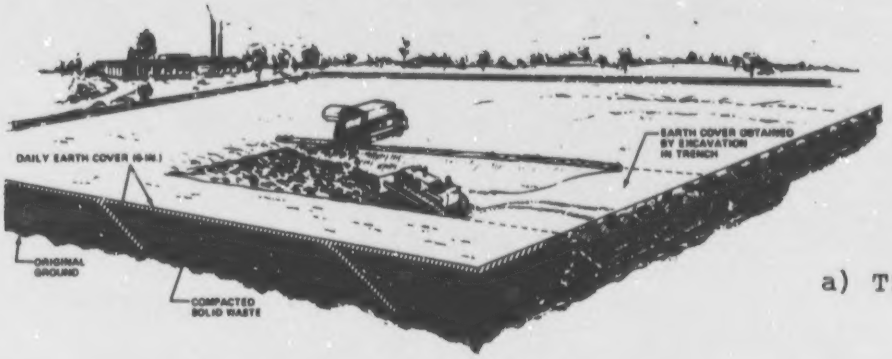
Planning and operation of sanitary landfill must include provisions for control of water pollution, control or odor and nuisance, and elimination of disease carrying vectors.

Roughly, one acre of land with a 15 foot compacted lift of solid waste will accommodate a population of 10,000 for a year. If additional lifts can be placed over the initial lift, the land area requirement will be reduced.

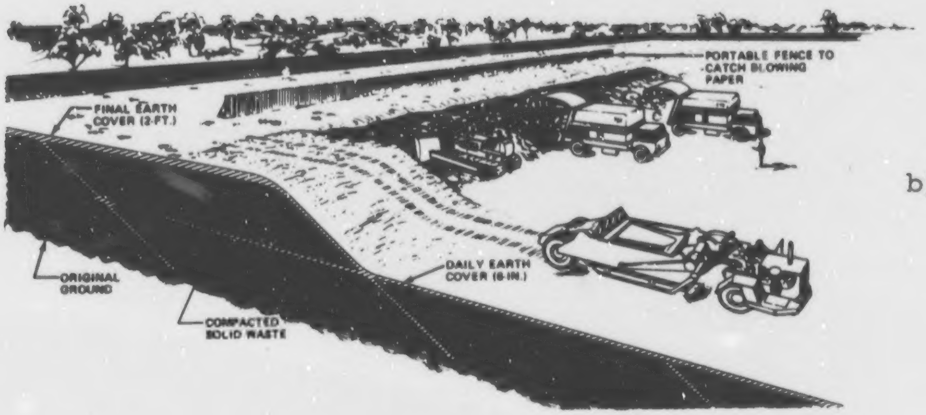
(2) Methods

Prevailing methods of sanitary landfill construction are generally divided into three categories which are described briefly as follows:

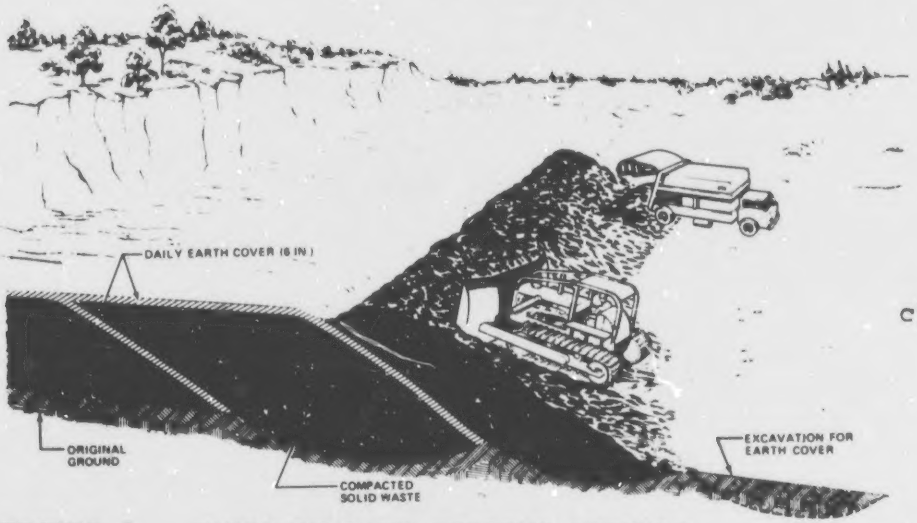
(a) The trench method, Figure 1a, is usually employed where flat or gently sloping land is the only marginal land available for solid waste disposal. The method is particularly suited to terrain which can be trenched with conventional earthmoving equipment and is based on the use of parallel excavated trenches. Starting at one edge of the land parcel, refuse is dumped into the first trench from its nearest side. At the end of each day's dumping, spreading and compacting, the refuse is covered with earth excavated from a second trench on the far side of the dumping edge. The completed area is given a heavy earth cover while the working face is given a light closing cover. When completed, the landfill


DAILY EARTH COVER (6 IN.)
EARTH COVER OBTAINED BY EXCAVATION IN TRENCH
ORIGINAL GROUND
COMPACTED SOLID WASTE

a) Trench Method


PORTABLE FENCE TO CATCH BLOWING PAPER
FINAL EARTH COVER (2-FT.)
ORIGINAL GROUND
DAILY EARTH COVER (6-IN.)
COMPACTED SOLID WASTE

b) Area Method


DAILY EARTH COVER (6 IN.)
ORIGINAL GROUND
EXCAVATION FOR EARTH COVER
COMPACTED SOLID WASTE

c) Ramp Method

FIGURE 1. SANITARY LAND FILLING METHODS
(Reference 8)

consist of a series of long, narrow refuse cells in parallel rows. The finished grade will usually be higher in elevation than the original ground surface.

(b) The area method, Figure 1b, is usually employed in low-lying areas such as tidelands, marshes, or swamps and where land depressions such as abandoned quarries, ravines, or canyons are available. In tideland applications, the site is usually inclosed with a dike. Refuse is dumped on the existing ground surface, spread in horizontal layers, and compacted. At the end of each day's work the surface is covered as needed with earth excavated from the area directly in front of the working face. If excavation is not possible the fill is covered with imported cover materials.

(c) The ramp method, Figure 1c, is used exclusively in filling natural or man-made depressions, such as deep ravines, canyons, or quarries. In this method, refuse is deposited and spread in layers on an angle against the side of the ravine to a predetermined height.

This height can extend 40 to 50 feet or higher. Cover soil is placed on the slope sides and top at regular intervals. In this operation the collection vehicles deposit their refuse at the base of the working face of the fill; cover is obtained from a point just ahead of the face.

Sanitary landfilling employs a wide variety of earth moving equipment. The principal types in general use are wheeled tractor bulldozers, crawler or track type tractor bulldozers, crawler tractors with bull clam or a front end loader, carring scrapers, and cranes with draglines of other such equipment. Specialized wheeled tractor compactor bulldozers equipped with special type compactor wheels and refuse spreading blades are also being used.

(3) Hazards

There are several problems that can arise at sanitary landfill sites. The most significant include the following:

(a) Water Pollution

A principal hazard of sanitary landfill

disposal is the possibility of fluids leaching from the fill and polluting the streams or ground water. Such problems can be prevented, or minimized, by proper site selection and by constructing the fill in such a manner that it does not become saturated. This can be accomplished by filling all space below maximum ground water level with inert material, providing an impervious dike around the fill to exclude flood waters or surface drainage from adjacent higher ground, and covering and grading the top of the fill to drain off much of the precipitation which falls on its surface.

Besides the problem of ground water pollution, filling of swamps and flood plain lands can have an adverse effect upon flood conditions. Also, the filling of natural land depressions may have an adverse effect on precipitation collection and entry into the ground water supply.

(b) Gases

Biological decomposition of refuse in a

sanitary landfill produce gases of which the three major components are carbon dioxide, methane, and nitrogen. Of the combustible gases, methane is the major constituent and hydrogen, when present, is minor in quantity. Whereas gas emission from the surface of sanitary landfills is not uncommon and this phenomenon is well known, travel of gases, particularly combustible gases, from landfills into adjacent ground is of newer concern. A recent study (Reference 5) has shown that these gases can move laterally significant distances from landfills into adjacent soils. If the gas is allowed to diffuse freely into an open space, where it is readily diluted by air, the surface concentration decreases to practically zero. However, if methane is trapped in a confined space, the concentration will build up to an inflammable level. Gas disposal techniques should be designed to eliminate problems associated with generation in the fill.

Implementation of both a barrier and venting system should proceed with the filling operation.

(c) Flies and Rodents

Fly and rodent control is a problem in any landfill operation. Fly control is best accomplished by using a cover material with a binder which is well compacted. A well compacted cover of 2 5/8 inches prevents fly emergence. With an uncompacted earth fill of 5-foot thickness, 90% fly emergence has been noted. Covering the refuse every night eliminates the attraction of rodents.

(d) Fires

Landfill fires also present significant control problems and require proper supervision of personnel and dumping procedures. Minimum fill area should be open at any one time. Watering down refuse tends to reduce possibility of fire while at the same time aiding compacting.

(e) Decomposition

The rate of decomposition or organic matter in sanitary landfills is affected by moisture, soil mixture, depth of fill, type of soil, aeration and temperature. Differential settlement of the surface of completed sanitary landfills presents a serious problem in the design of surface and subsurface structures and, thereby, greatly inhibits the use of the completed site. Settlement estimates and methods of control must be utilized.

Land uses of completed sites are affected by both gases and differential settlement. Therefore, land uses tend to be athletic fields, gardens, golf courses, parks parking lots, playgrounds, or other such uses. Buildings would provide traps for methane and thus allow concentration to reach inflammable levels.

(4) Site Classification

The general classes of disposal sites have been established based on a consideration of the geology, hydrology, topography, and nature of the wastes.

(a) Class I Disposal Site

No limitation as to either solid of liquid wastes. Sites located on non-water-bearing rocks or underlaid by isolated bodies of unusable ground water, which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable wasteway, and where safe limitations exist with respect to the potential radius of percolation.

(b) Class II Disposal Site

Limited to ordinary household and commercial refuse of the nature indicated below:

Empty tin cans
Metals
Paper and paper products
Cloth and clothing
Wood and wood products
Lawnclippings, sod, and shrubbery
Hair, hide, and bones
Small dead animals

Roofing paper and tar paper

Unquenched ashes mixed with refuse

Market refuse

Garbage

All materials acceptable at Class III Disposal Sites

Sites underlain by usable, confined, or free ground water when the minimum elevation of the fill can be maintained above anticipated high ground water elevation, and which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable wasteway.

(c) Class III Disposal Sites

Limited to nonwater soluble, nondecomposable inert solids of the nature indicated below:

Earth, rock, gravel,and concrete

Asphalt paving fragments

Glass

Plaster and plaster board

Manufactured rubber products

Steel mill slag

Clay and clay products

Asbestos shingles

Sites so located as to afford little or no protection to usable waters.

Reference 5 covers sanitary landfills in general and the county of Los Angeles operation particularly in some detail. This report gives considerable data on twelve different sanitary landfill sites in Los Angeles.

b. Rail Transport of Solid Waste (Reference 2)

(1) Why Rail Haul

Rail transport is treated next because it is in effect an extension of sanitary landfill. The several systems shown in Table 6 all terminate with sanitary landfill. The reason for this is that the cost of incineration per ton of combustible wates is estimated to range from $5.00 to $7.00 per ton for new installations using the most up to date technologies. In contrast the average cost of sanitary landfilling is reported to range from $0.50 to $2.00 per ton.

Overall System Number	Position and Number of Major Systems Building Block				
	a	b	c	d	e
I	Local Collection	Transfer Station	Rail Haul	Sanitary Landfill	
II	Local Collection	Inciner- ation	Transfer Station	Rail Haul	Sanitary Landfill
III	Local Collection	Transfer Station	Rail Haul	Inciner- ation	Sanitary Landfill
IV	Local Collection	Com- posting	Transfer Station	Rail Haul	Sanitary Landfill
V	Local Collection	Transfer Station	Rail Haul	Composting	Sanitary Landfill

TABLE 6. Major Alternatives for the Position of Rail Haul as an Integral Part of Waste Disposal Systems. (Reference 1)

Rail-haul should be viewed in light of the fact that collection and transportation is often estimated to account for about two-thirds or three-fourths of the total solid waste disposal bill. Also, this disposal problem is especially acute in the densely settled urban areas of the northeast. This area contains an extensive rail network as well as suitable potential mass disposal sites.

All currently used disposal methods require at least some land for the ultimate disposition of the wastes or the waste residue. However, in urban areas land is not only in short supply, it is also in strong demand for more attractive or productive use. In competing for the decreasing amount of land, solid waste disposal often is left the loser. As a result, more and more waste needs to be taken out of the immediate areas where it originates. Thus transportation is becoming an increasing requirement in the development of solid waste management systems. Once "out-of-town" disposal is considered, "regional" and "super-regional" systems must be investigated. The logic of this situation implies, specifically, that long distance transport must be evaluated along with volume reduction to an ever increasing degree. Railroads are a prime example of the low cost, high tonnage, and ubiquitous transportation that should be investigated carefully with respect to such long distance transport.

(2) Benefits

A feasibility study of rail transport of solid waste has been sponsored by the HEW Bureau of Solid Waste Management. As discussed in an interim report (Reference 2), the benefits potentially achievable through a solid waste rail-haul system, appear to be as follows:

(a) A strong possibility of low direct waste disposal cost. Currently, it is calculated, that solid waste rail-haul will cost about $4.00 to $4.50 per ton F.O.B. transfer station (i.e. not including the cost of local collection). These costs, including investment and operation, break down as follows: Transfer station, about $1.00 to $1.50 per ton; rail haul, about $2.00 per ton; and disposal, about $1.00 per ton.

(b) A change from inadequate methods of disposal to desirable methods and a reduction of air and water pollution as well as other environmental health hazards. Solid waste rail-haul does not contribute to air pollution in any significant degree. The extreme flexibility in the location of the disposal site allows a wide choice among sites according to their geological suitability. The cost per ton to provide proper protection against water pollution, when soil conditions require such action, are not expected to be prohibitive because of the size of the disposal operation. Finally the necessary dust, noise and odor controls appear to be achievable conventionally and economically.

(c) A better utilization of existing rail installations in urban, as well as rural areas. Solid waste rail-haul appears capable of developing a considerable amount of new business for the nation's railroads. As a matter of fact, solid waste transport might evolve into a position ranking it among the largest rail shipment categories.

(d) A capability for land reclamation and the conversion of worthless mining or other land into an active resource. Solid waste rail-haul is capable of performing land reclamation without any cost to the respective property owners. In addition, results can be demonstrated fast because of the refuse quantities involved.

(e) The establishment of an effective and reliable solid waste disposal system. Rail transport of solid wastes appears capable of providing a key link for a relatively complete system of disposal. It tends to require proven system elements and is able to funtion regardless of the usual changes in weather. Also, it appears to be relatively immune to damages occurring in some part of the system and will ensure, as a rule, a speedy method of removing solid wastes from high density urban areas.

(f) A potential for widespread application. Although total system configuration and implementation might be quite large, solid waste rail-haul appears capable of handling large, as well as small, individual input loads without an undue sacrifice of effectiveness. Most likely, many communities over the entire geographic range of the United States and Canada can participate in the system that might be developed on a regional, super-regional, state, and/or interstate basis.

(g) A high degree of flexibility with respect to work-load. Solid waste rail-haul can accommodate gradual as well as sudden increases in the total, as well as in the local, workload while requiring only relatively small adaptations in the capacity of the system installation. Conversely, system cost can be cut back drastically if the workload decreases.

(h) Attractive implementation opportunities. Concerning the individual system elements, the experience in other fields of industrial/commercial endeavor indicates that the system

1. is safe to operate
2. can be implemented rather rapidly, i.e. within twelve months, and
3. offers potential users many options for the organization of the effort.

Solid waste rail-haul implies sanitary landfill as the means of disposal. No existing landfill is as large as the one which might become realistic in a solid waste rail-haul system. The largest system actually operated disposes of 8000 tons of refuse per day (Fresh Kills, Staten Island, NYC). In contrast, network analysis suggests that, for solid waste rail haul, a site should be capable of handling on the order of 30,000 tons of solid wastes per day.

(3) Disposal Sites

Potentially, a variety of landfill sites might be used. By type, the following alternatives can be identified:

(a) Sites commonly used in existing landfills. Solid waste rail-haul landfilling differs from existing methods primarily because of the scale of operations. It appears feasible to continue the use of the presently used methods with some modifications. Due to the kind of equipment applied, a trench, for example, might be 100 to 200 feet wide and 50 to 100 feet deep.

(b) Pits and Quarries. Pits and quarries exist almost universally but do not appear to lend themselves well to rail-haul solid waste disposal. As a general rule, they do not have the needed capacity, and perhaps lack a sufficient amount of inexpensive cover material. However, the effective capacity of pits and quarries might be increased substantially by the use of highly compacted refuse. Also, the soil used for intermediate cover may, perhaps, be substituted by man-made materials such as urethane foams of asphalt based substances. These materials can be fabricated to be porous or non-porous, elastic or rigid, and fire resistant as well as insect and rodent repellant. Indications are given that some of these materials may be put in place at a cost from one to five cents per square foot.

(c) Open pit mines. Open pit mines are very large but few in number. Examples include the iron ore mines in Minnesota and the copper mines in Utah or other states at the same longitude. These mines would probably be adequate for the disposal of solid waste in these areas, but are not ordinarily available. The current rate of technological advance tends to extend the life of a mine by making it economical to mine lower grade ores. As a result, mine owners are reluctant to forego this often very profitable opportunity by having their pits filled with solid wastes.

(d) Scrub land. Scrub land exists to some extent in every state and province and appears to be a useful type of disposal site. However, scrub land is inoffensive and does not impel people to try to reclaim it. Consequently it is not likely to be used. Use of any given site would depend on accessibility, on remote location, and on local soil and water conditions.

(e) Marshes. A careful distinction must be made in the case of marshes. As a matter of conservation, one cannot arbitrarily seize on marshes for landfill sites. Some marshes are wildlife refuges or in tidal areas have an important bearing on aquatic life and the fishing industries. Yet, there are marshes which have no such values and might be suitable sites. As in all other cases, but specifically here, the site selection must take into account the potential for water pollution, flood damage and the like. A number

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of good examples do exist where marshes have been used for landfill with highly beneficial results. Nevertheless, public relations appear to be the main problem in the disposing of solid wastes in useless marshes through sanitary landfill.

(f) Active topography developments. Due to the large amounts of materials involved, rail-haul offers ample opportunities for substantial topography engineering. The material might be used to build hills in level areas, facilitate flood control, if proper sealing is guaranteed, and to develop recreational complexes.

(g) Creations of offshore islands and/or land reclamation in lake and coastal areas. The large amounts of material rail-haul is capable of concentrating into one area offers distinct possibilities of creating offshore islands and of developing land by partial filling of large bodies of water. In this case proper diking and sealing are absolutely necessary to avoid any water pollution.

(h) Ocean disposal. Oceans offer almost unlimited space for disposal of solid wastes, if the wastes can be processed in a way to prevent harmful or undesirable effects on the environment. It would require that the rail-haul segment of the disposal system terminate at port cities or other suitable seaside locations.

The economics of ocean disposal appear to be rather attractive since no site preparation or on site operations are required. For a haul distance of about 100 miles offshore and a volume of about 20,000 tons per day, the necessary shipping costs have been estimated at 25 to 40 cents per ton. The shipping could be done in ocean-going bottom-dump barges or especially designed sea-going vessels.

It should be highlighted that ocean disposal requires definitely a suitable processing of the solid waste materials.

(i) Active and abandoned strip mines. The possibility of disposing solid wastes through active strip mines operations has captured the attention of mine owners as well as officials from various levels of government. The U.S. Department of the Interior estimates that some 3.2 million acres, or 5000 sq. miles of land, have been disturbed by surface mining as of 1 January 1965. Only about one-third of this acreage is estimated to have been reclaimed, leaving roughly 2 million acres requiring reclamation. Although it is difficult to estimate the annual increase in acreage disturbed by surface mining, the figure cited for 1964 is 150,000 acres. About 41% of the land disturbance is caused by the mining of coal; 26% sand and gravel; 8% stone; 6% gold; 6% phosphate; 5% iron; 3% clay; and 5% all others.

Furthermore, the selection of coal strip mines for disposal sites for rail-haul systems appears to be supported by the geographical location of the mines. In terms of actual percentage, states east of the Mississippi account for 95% of the total coal produced. The states of Kentucky, West Virginia, Virginia, and Pennsylvania rank highest in the total number of operative coal mines within their borders. Thus, the geographical distribution of coal mines appears to be very favorable for solid waste rail-haul since a significant share of the nation's highly urbanized areas are found east of the Mississippi.

Solid waste disposal in abandoned strip mines might be considered a special type of ordinary sanitary landfilling. One disposal opportunity is provided by the abandoned last trench, another is found in the gaps between the spoil banks. This latter opportunity blends directly into the reclamation requirements of many states and would help the owners defray their reclamation cost. In a completely different approach, it also might be possible to work abandoned strip mines backwards in order to use the total area to better advantage.

Finally, it also appears advantageous to blend solid waste disposal into normal activities of an operating strip mine. (See Fig. 2). This procedure would add little or no cost to the mine operation but could, on the other hand, provide for all the cost of disposal space and of covering material for the wastes.

c. Incineration (Reference 9,10)

Incineration is a controlled combustion process for burning solid, liquid, or gaseous materials to an inoffensive gas and a residue containing little or

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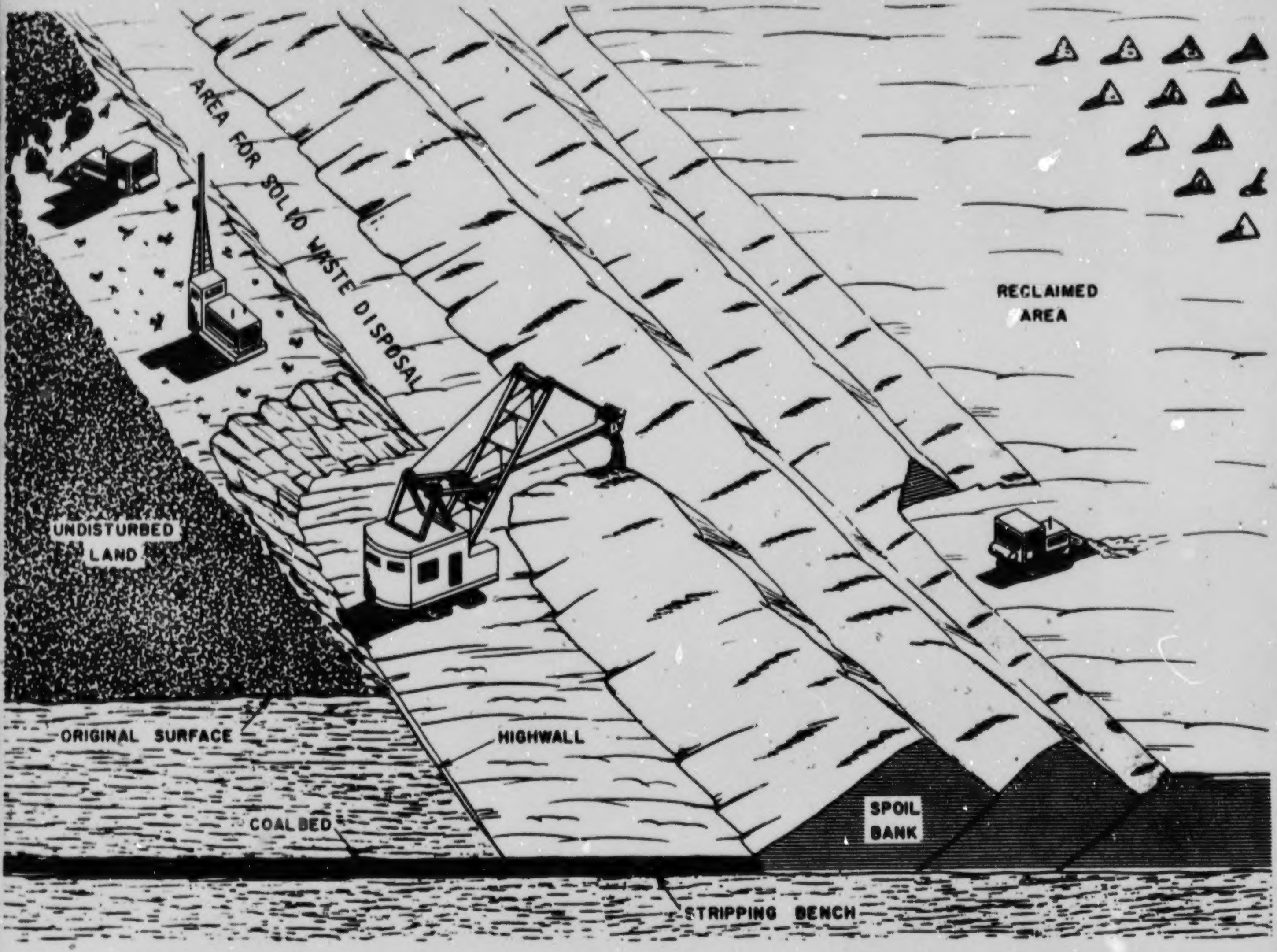
AREA FOR SOLID WASTE DISPOSAL
RECLAIMED AREA
UNDISTURBED LAND
ORIGINAL SURFACE
HIGHWALL
SPOIL BANK
COALBED
STRIPPING BENCH

FIGURE 2. OVERVIEW OF ACTIVE STRIP MINE OPERATION (Reference 2)

no combustible material. The volume of municipal solid waste can be reduced 80 to 90% by incineration. In the process usually 98 to 99% by weight of the combustible material can be converted to carbon dioxide and water vapor. Total weight reduction is commonly 75 to 80% based on the weight of the as-charged solid waste, reduced to a dry residue. The end products of municipal incineration, however, must be disposed of. These end products include the particulate matter carried by the gas stream, incinerator residue, siftings, and process water. Incinerator residue consists of noncombustible materials as well as combustible materials not completely consumed in the burning process.

An incinerator requires a large capital investment, and operating costs are higher than for sanitary landfill. A survey of over 170 municipal incinerators found that the average capital cost was approximately $6150 per ton (24 hour capacity) and an average operating cost of $5 per ton. Skilled labor is required to operate, maintain, and repair the facility. Thus capital and operational costs must be compared with the cost of alternate disposal methods, and full consideration must be given to the effect of the method on the community and its neighbors. Since collection and transportation costs amount to approximately 75% of the total solid waste disposal bill, incineration is especially advantageous where land within economic haul distances is unavailable for disposal by sanitary landfill methods.

(1) On-site incineration. On-site incinerators are those used inside and outside houses, in apartment buildings, stores, small industries, hospitals, and other institutions to burn refuse produced on the premises. The advantage is that the amount of combustible refuse that must be collected and disposed of is reduced by the amount that is burned, and that the requirement for on-premises storage is reduced. The disadvantage is that improperly designed or operated on-site incinerators do cause considerable air pollution. New York City has for many years prohibited incinerators in buildings which house less than twelve families, largely because of improper maintenance and excessive pollution. Typical incinerators range from 85 pounds per day capacity to a maximum of 3,400 pounds per day which would satisfy the needs of a 2000 tenant building. The

average incinerator design capacity is about 350 pounds per day.

The residue has one-tenth to one-fifteenth the volume of the original refuse, with a weight reduction of at least 75%. Most of this residue is in the form of bottles, cans, and ash, with 5 to 15 percent combustible matter, largely food products. The following composition of residue has been reported. (Reference 7)

Metal and glass over ½ inch	64%
Ash from combustible matter	12
Unburned combustible matter	16
Moisture	8

There are two general types of incinerators available, the major difference being the method of feeding the refuse from the various floors into the furnace.

Many of the existing incinerators could be brought up to satisfactory performance by incorporating the design factors that have been found beneficial in the new units, without major changes or cost. The principal elements are:

(a) Auxiliary burner in the furnace or primary chamber to ignite the refuse and maintain

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desired temperature in conjunction with the heat from the refuse. Over-fire air fans with mainfold and nozzles to assure adequate turbulence and complete burning of the volatile combustibles.

(b) Programming electric clocks with 24-hour dials and adjustable contact pins to permit starting and stopping of the above items at preset intervals. All controls to be inclosed in tight steel box.

(c) Adequate flyash removal equipment

(2) Central Incineration

Many systems of incineration have evolved over the years as technology improved, as living habits changed, and as solid waste collection practices developed. Although considerably different in construction and operation, it is clear that all successful systems of central municipal mixed refuse incinerations include provisions for carrying out the following essential functions:

(a) Receiving loads of mixed refuse at varying rates of supply.

(b) Measuring the quantity of refuse received.

(c) Storing a "buffer" amount of refuse in a sanitary, accessible, yet nuisance-free manner.

(d) Sorting, mixing or otherwise preparing refuse for incineration.

(e) Feeding the refuse to a furnace at a controlled rate.

(f) Drying the refuse sufficiently to permit ignition of combustibles.

(g) Burning the refuse to produce essentially inert solid residue and tolerable gases.

(h) Dissipating the heat of combustion.

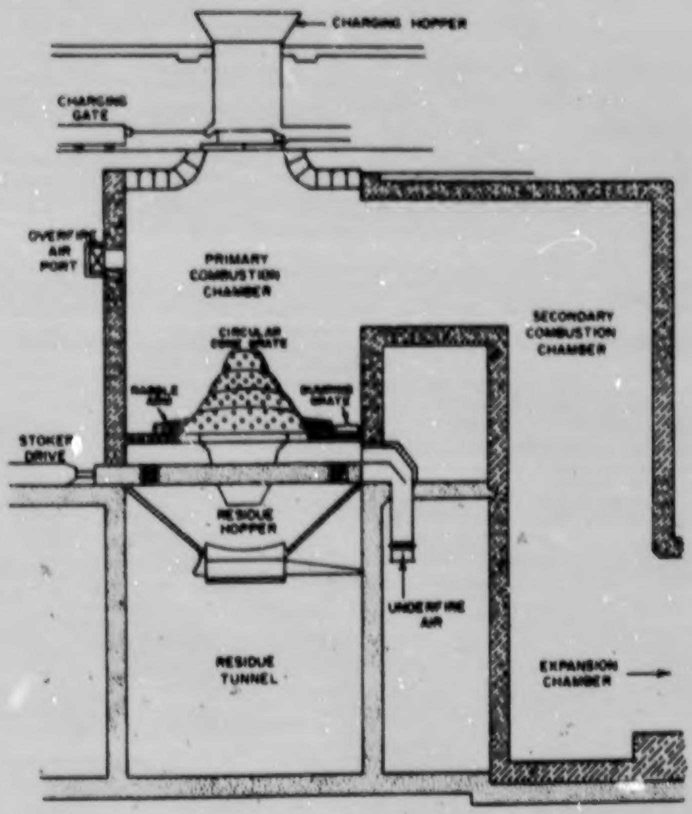
(i) Collecting, cooling and removal of non-combustible residue solids.

(j) Cleaning and discharging effluent gases and liquids in an acceptable form.

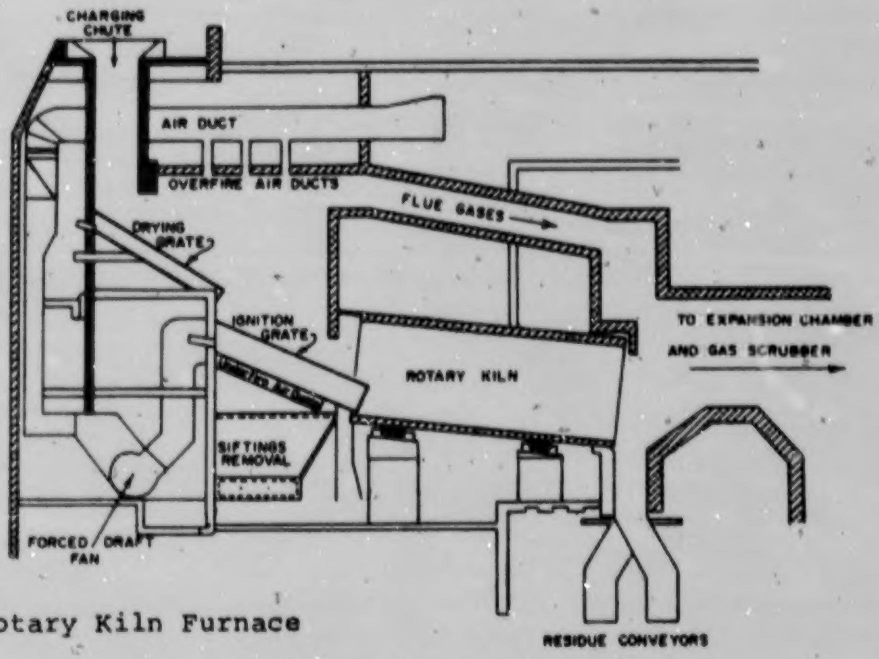
(k) Controlling the process for safety, efficiency, economy, and community acceptance.

(l) Protecting the personnel and equipment from the elements, from dangerous refuse, and from careless operation.

Furnaces commonly used for the incineration of municipal solid waste are the vertical circular furnace, the rotary filn furnace, the rectangular furnace, and the multicell rectangular furnace. (Figure 3)

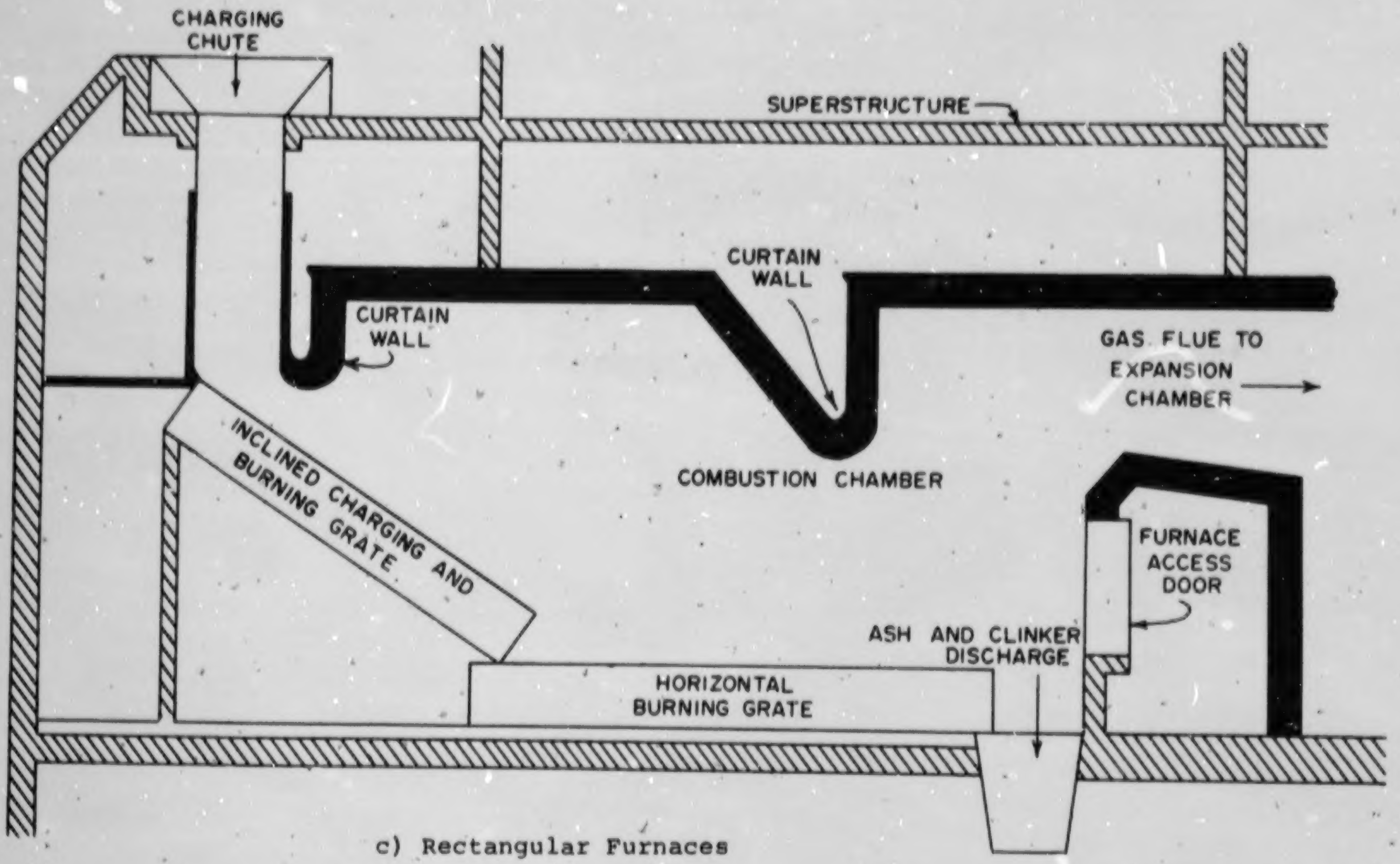

CHARGING HOPPER
CHARGING GATE
OVERFIRE AIR PORT
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
CIRCULAR CONE GRATE
RABBLE ARM
DUMPING GRATE
STOKER DRIVE
RESIDUE HOPPER
UNDERFIRE AIR
RESIDUE TUNNEL
EXPANSION CHAMBER

a) Vertical Circular Furnace


CHARGING CHUTE
AIR DUCT
OVERFIRE AIR DUCTS
FLUE GASES
DRYING GRATE
IGNITION GRATE
ROTARY KILN
TO EXPANSION CHAMBER AND GAS SCRUBBER
SIFTINGS REMOVAL
FORCED DRAFT FAN
RESIDUE CONVEYORS

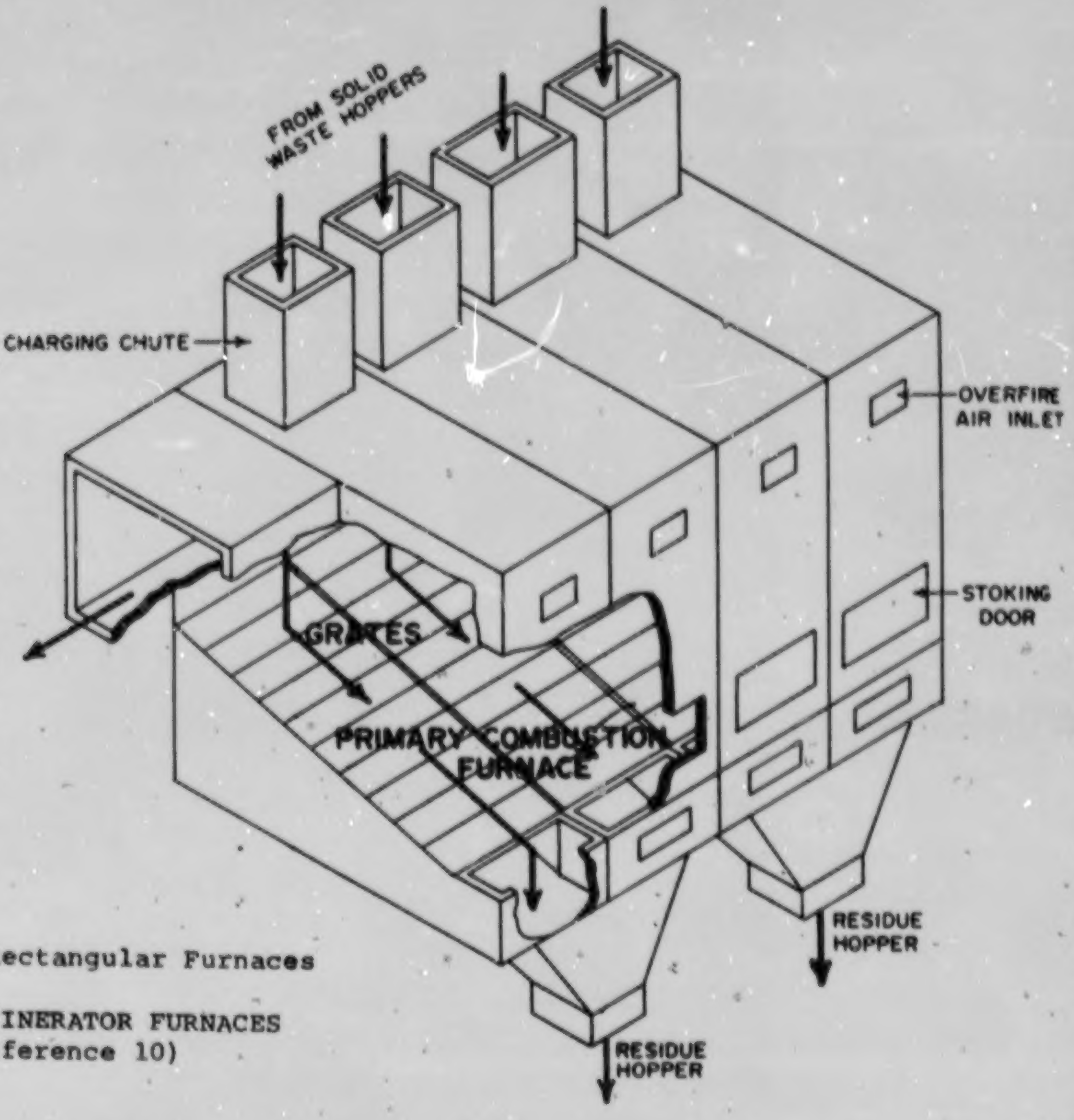
b) Rotary Kiln Furnace

FIGURE 3. INCINERATOR FURNACES
(Reference 10)


CHARGING CHUTE
SUPERSTRUCTURE
CURTAIN WALL
CURTAIN WALL
GAS FLUE TO EXPANSION CHAMBER
INCLINED CHARGING AND BURNING GRATE
COMBUSTION CHAMBER
FURNACE ACCESS DOOR
ASH AND CLINKER DISCHARGE
HORIZONTAL BURNING GRATE

c) Rectangular Furnaces

FIGURE 3. INCINERATOR FURNACES
(Reference 10)


FROM SOLID WASTE HOPPERS
CHARGING CHUTE
OVERFIRE AIR INLET
STOKING DOOR
TO SECONDARY COMBUSTION CHAMBER
GRATES
PRIMARY COMBUSTION FURNACE
RESIDUE HOPPER
RESIDUE HOPPER

d) Multicell Rectangular Furnaces

FIGURE 3. INCINERATOR FURNACES
(Reference 10)

Time, temperature, and turbulence are commonly called the three T's of combustion. When solid waste is exposed for a sufficient time to a turbulent hot atmosphere, the waste will be satisfactorily incinerated. The function of the turbulence is to insure mixing of each volume of gas with sufficient air for complete burning of volatile combustible matter and suspended particulates.

In the combustion process, oxygen is needed to complete the chemical reaction involved in the burning. The air necessary to supply the exact quantity of oxygen required for the chemical reaction is termed stoichiometric or theoretical air. Any additional air supplied to the furnace is termed excess air and is expressed as a percentage of the theoretical air. To supply adequate air for complete combustion and to promote turbulence, a minimum of 50% excess air should be provided. Too much excess air, however, can be detrimental because it lowers furnace temperatures. In general, refractory furnaces require 150 to 200% excess air, whereas water tube wall furnaces require only 50 to 100% excess air.

Combustion air can be preheated to 200 to 300°F. Once in the furnace, the temperature rises rapidly. Immediately above the burning waste, the temperature of the burning gases generally ranges from 2100 to 2500°F and it may reach 2800°F for short periods of time in localized areas. When gas leaves the combustion chamber it should be between 1400° and 1800°F. The gas temperature leaving the stack can be expected to be 1000°F or less. Before they enter the air pollution control devices the gases should be cooled to 500° to 700°F.

It is desirable to have auxiliary fuels available for:

(a) Furnace warm up

(b) Promotion of primary combustion when the solid waste is wet or does not contain an adequate BTU content for good combustion.

(c) Completion of secondary burning to ensure odor and smoke control.

(d) Supplementation of heat for heat recovery units when the supply or heat value of the solid waste is not sufficient.

The concept of the recovery and use of heat produced during incineration has always intrigued engineers and municipal officials. Unless the heat is used, it is wasted. This represents lost energy and may also contribute to thermal pollution. In the U.S. most engineers hesitate to design systems to reclaim waste heat because of the added cost of the heat recovery equipment, the variability of the heat value of the solid wastes, and the difficulty of matching the supply of waste heat to the demand for heat.

Most U.S. incinerators with heat recovery equipment use recovered heat for in-plant use only. These plants use recovered heat to generate electricity, supply hot water, and heat the incinerator plant during cold weather. Recovered heat has also been used at one plant for desalting sea water for in-plant use and for supplying steam power within the incinerator plant and to nearby sewage treatment plants. Several U.S. plants supply steam to heating systems and to institutions such as hospitals.

The sale of steam to power generation plants is also possible. The most practical means of using waste heat is to supply steam to a large power system with a minimum demand greater than the maximum incinerator output.

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Under development at the present time by the Combustion Power Company is an incinerator which will be used to generate electricity using the high temperature gases of combustion. (Reference 11) The incinerator is a fluidized-bed incinerator which burns solid waste at high pressure. The hot gases that are produced power a turbine that drives an electric generator. It is estimated that the unit will produce 15,000 kilowatts while processing 400 tons of solid waste daily. This would represent 5 to 10 percent of the power requirements providing the waste and partially offsets the cost of solid waste disposal. A one-tenth scale pilot plant is scheduled for completion in 1972 and a full scale prototype after 1974.

Air pollution control is an expanding requirement in incinerator operation. Odors, gaseous emission, and suspended particulate emission are the types of pollutants present.

The best approach to the control of odors generated in the drying and combustion process is maintenance of adequate retention time and sufficient temperature to ensure complete combustion of hydrocarbon vapors to carbon dioxide and water. If the temperature at the exit to the furnace is kept above 1400°F, temperatures within the combustion chamber will be sufficient to eliminate odors.

Both nitrogen oxide and sulfur oxide emission occur in solid waste incineration, but the amount per ton of fuel burned are several orders of magnitude below those involved in the combustion of fossel fuel. Solid waste is a "clean fuel" from the standpoint of sulfur content with about 0.26% by weight compared to 1 to 3% for most coals and oils. Further, there is evidence to suggest most of the sulfur is retained in the ash. Nitrogen oxide emission per ton of fossil fuel are over 10 times that of an incinerator and since at this time nitrogen oxides are not considered a problem with fossil fuel, they should present no problem with solid waste incineration. Some concern has been expressed about emissions of hydrogen chloride that might occur as a result of the incineration of certain plastics. This gas is highly soluble in water and can be effectively removed by water scrubbers.

Suspended particulate emission is the real air pollution problem and some type of collection system is necessary. The simplest and oldest form of particulate collector is the settling chamber. Prior to 1953 or 1954 this was the only type collector used in incinerator plants. Their efficiencies range from 10 to 35% and they are unacceptable. Another type collection device is the wetted baffle or baffle spray system. These systems have been used on over half of the new installations since 1957, yet their collection efficiency ranges from 10 to 53%, and one installation with a spraying section and secondary baffle claims 69.4%. Cyclones and multiple-cyclones have been used in about 20% of the installations since 1957 and published data indicate efficiencies in the range of 60 to 65%. Approximately 20% of the installations since 1957 have been equipped with hot scrubbers. Analysis indicates an efficiency capability in the range of 94 to 95%. Electrostatic precipitators have been used in Europe for a number of years but have not yet been operated on a full scale bassis in the U.S. Several new plants under construction will use electrostatic precipitators with design efficiencies in the 90 to 98.5% range. Except for pilot installations, fabric filters have not yet been applied to incinerators and their use must be considered experimental.

(3) High-Temperature Incineration

High-temperature incineration is in the experimental stage. Two such experiments are considered here. Both use a vertical shaft furnace operating between 2600 and 3200°F. Thus, combustibles are incinerated and non-combustibles are converted into a molten residue which flows as a liquid stream from the base of the unit.

(a) Whitman, Massachusetts Test Facility (Reference 12)

Sponsored by a HEW Grant, a high-temperature incinerator was operated as a test facility in the Town of Whitman, Mass. from 1966 until 1969. The objective and conclusions were as follows:

1. Objectives: The test was conducted to determine the degree to which the principle had been developed for the reduction of municipal refuse. Specific items of interest were:

a. Capacity in tons per hour of refuse input per unit size of furnace, based on regular municipal refuse.

b. Ability to operate continuously over a period of days.

c. Consumption of coke, limestone, flux, power, water and auxiliary fuel if any.

d. Refractory wear and life expectancy.

e. Physical and chemical analysis of the slag.

f. Physical and chemical analysis of the refuse.

g. Emissions of gases and particulate matter from the stack.

h. Evaluation of the unit as a municipal incinerator.

2. Conclusions: Conclusions drawn from the tests were as follows:

a. In its state of development and method of operation during the March 1968 tests the pilot incinerator did not perform satisfactorily because of:

Low refuse firing rate

High coke consumption relative to refuse incinerated

Inability to drain molten iron and slag as necessary to maintain continuity of operation

Excessive limestone requirement

Excessive emission of fly ash

High labor requirements

Short refractory furnace lining life

b. The molten residue from the unit was free of putrescible and combustible matter and could be deposited in landfill without cover. It would not attract vermin or rodents, and it was odorless and sterile.

c. A high yield of iron from the refuse was produced in the form of spherical and flattened drops that could be easily separated magnetically.

d. The electrical power consumption of the pilot plant was 48.66 kw. per hour of operation. This quantity is not indicative of the power consumption to be expected in a full'scale installation.

e. The water in the residue quench tank was cooled by circulation through a blower cooled heat exchanger. Hence, furnace water consumption was the moisture on the granulate, about 14 gallons per ton of refuse.

f. The refuse burning rate is limited by the rate of melting of the inerts and/or by the loss of solids as carryover from the furnace. The carryover increases rapidly above 12 ft. per second of gas velocity as loose paper, foil, plastic film wrappings, and sweepings do not fall into the coke bed but are immediately carried upward from the charging chute.

g. Based on tests, the burning rates for several sizes of incinerators would be as follows:

Furnace Diameter Ft.	Top Diameter Ft.	Refuse Rate Tons/Hr.
3	5	1.60
4	6.7	2.84
5	8.3	4.45
6	10.0	6.40
7	11.7	8.72

h. The shaft furnace is only the primary combustion chamber of a complete incinerator plant.

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A secondary combustion chamber or chambers will be required to complete the combustion of the carry-over solids. A dust collector will be required after the secondary chamber to reduce the particulate loading of the exhaust gases.

(b) The Torrax System (Reference 13)

The Torrax System for high temperature solid waste disposal uses supplemental energy in the form of very high temperature pre-heated air. Combustion air is filtered and then heated by passing it through silicon carbide tubes around which flow the hot combustion products of an ordinary fuel. The air is heated to 1500-2000°F.

Refuse is charged periodically into the top of the Gasifier, and its level maintained within prescribed limits. As the refuse slowly descends in the gasifier, most of the readily combustible materials never reach the high temperature zone at the bottom, because the hot gases permeating up through the refuse pyrolyze the organic materials to form combustible gases.

The material at the bottom is composed of difficult-to-burn objects, pyrolysis char, and non-combustibles. These materials are partially oxidized to create additional combustible gas, or liquified to form a complex silicate slag and a mixture of molten metal. Temperatures at the base are 2600-3000°F. A liquid mixture flows from the gasifier into a chamber filled with water where an aggregate-quality frit is formed from the slag and the metal is frozen into small droplets. The gases flowing from the gasifier contain no free oxygen and consist mainly of carbon monoxide, hydrocarbon gases, and nitrogen. Entrained in this gas stream are particles of carbon, fly ash, etc. This combustible gas solid mixture is reacted in the igniter with ambient air.

The remaining equipment in the process serves to extract heat from the gases issuing from the igniter and to cleanse the gas stream of particulate matter.

d. Composting (Reference 14)

Composting is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus-like material which may be used as soil conditioner. Modern scientific composting has been described as a rapid but partial decomposition of moist, solid organic matter by the use of aerobic microorganisms under controlled conditions. Although in the late 1960's there were only a few composting plants in which municipal refuse was treated in the United States, experiences in Europe and experimental operations in the U.S. indicate that capital and operating cost of compost plants may compare favorably with incineration. The major advantage of the process appears to be that it produces a potentially marketable and useful product. However, unless some economically beneficial use is actually made of this end product, composting will be of limited value as a means of municipal refuse disposal. In addition, since not all materials are compostable, it is necessary to use sanitary land filling for the inorganic wastes.

e. Hog Feeding (Reference 9)

In colonial times, the problem of garbage disposal in large cities was "solved" by turning pigs loose in the street to serve as scavengers. As cities grew, owners of small farms in the outlying areas found it profitable to collect all or part of a city's garbage as food for their livestock. As the garbage disposal problem became more acute and regular garbage collection became a matter of public health, city governments began to contract with individual farmers to collect all the garbage of the city and many cities maintained hog farms for the disposal of garbage.

Despite the fact there is a statistical correlation between the practice of feeding raw garbage to hogs and the relatively high incidence of trichinae infection in humans in the U.S., the practice was not changed for many years. The rapid spread of a virus disease of swine between 1953 and 1955 promoted most states to enact legislation prohibiting feeding of raw garbage to swine. A World Health Organization report dated 1967 stated that one in six persons in the United States has trichinosis - the highest rate in the world. In 1968 Wisconsin completely outlawed feeding any type of garbage to swine. Because of the difficulty of preparing garbage properly, it is important that all states enact this prohibition.

When laws required that garbage be disinfected before it could be fed to swine, the problem of how to do it arose. To insure necessary and adequate protection of people, it is necessary that food wastes be cooked at 212°F for 30 minutes. Cookers of every type and size were soon developed, but a great deal of experimentation is still going on to find the best method of both thorougly and economically cooking the garbage. However, the feed value of commercial garbage has been enough to induce continuance of a surprisingly substantial amount of such feeding. The U.S. Department of Agriculture reported that for June, 1968 that there were 8,794 premises on which 842,911 hogs were being fed over 10,000 tons of garbage daily.

Residential garbage ordinarily has the poorest value as hog feed. It invariably has in it significant amounts of inedible materials such as glass and razor blades. Commercial and institutional garbage also contains inedible materials---paper, china, lamp bulbs, silver, napkins, cigarette and cigar butts. Restaurant garbage exceeds residential garbage in nutritional value, however, primarily because of the larger quantities of inedibles in residential garbage. Also, garbage is usually collected more frequently from commercial establishments and it is in better condition for feed, especially in summer. Market garbage is predominantly fruits and vegetables and must be mixed with other foods to make it suitable for hog feeding. Military installations are usually a good source of food waste for swine feeding. The garbage is from well balanced meals and the inedible wastes are separated from the edible waste better than in other sources of garbage.

While garbage shall continue to be important as hog food, hog feeding is not overly important insofar as refuse disposal. The total amount is comparitively small, only edible garbage can be disposed of in this manner and separate collections are required.

f. Recycling

The best way to dispose of waste products is to find uses for them. This means either salvage usable material or convert the refuse to a usable form. Either case is an example of recycling.

Obviously scrap metal can serve a useful purpose over and over again. The largest source of scrap iron and steel is sometimes called "prompt industrial", the shavings, the turnings, the leftovers, the bits and pieces from newly manufactured products. They present no real problem; their composition is easily defined. They are gladly reworked and reused by industry.

It is the second largest source of scrap iron and steel that creates the difficulty--the millions of automobiles that have been and will be junked. An industry has sprung up to take care of this problem, but as yet is not operating too successfully. More federally supported research is needed on means for producing uniform scrap from auto hulks, and on uses other than for scrap steel. A problem like that of the automobile is that of the 70,000 to 80,000 old freight cars discarded each year. A single car is about 40 feet long and weighs up to 27 tons. A typical "all steel" boxcar will contain about 4 tons of wood which must be burned or stripped away before the steel frame and other parts can be cut up with torches, or sheared, or crushed in big machines. The open burning, formerly practiced, is not long possible because of the air pollution requirement. Unless suitable methods are found, the car dismantling industry will fail, creating an even greater problem in thousands of unwanted freight cars.

As far as the automobile is concerned, the U.S. Bureau of Mines tates that automobile scrappage has reached a rate that can provide over 9 million tons of ferrous and nonferrous metals annually. The problem, however, is to separate them from each other and from the glass and combustible materials within the economics of the scrap market and with due consideration for air pollution. Incinerators can burn away combustible parts and some of the nonferrous metals can be removed by manual labor. The remainder can be processed by crushing or shredding to put it into a form acceptable for reprocessing. The machinery required to accomplish this is massive and expensive and the whole enterprise becomes involved in economics. A large operation is required to support the capital cost, and this means a large source of junked cars available without much transportation expense as well as a close and favorable scrap market.

Salvaging of other disposables is possible. The federal government, for example, has regular salvage and scrap separation for its vast waste-handling facilities. The General Services Administration in its Washington region office saved $350,000 from the salvaging of waste paper along in 1966. A score of composting plants in the United States reduces the volume of domestic waste and paper and return it in the form of fertilizer to the land.

Nonferrous metals contained in incinerator residues represent a natural resource that currently is ending in landfill. The United States Bureau of Mines has operated a pilot plant at the College Park (Md.) Metallurgy Research Center for approximately a year which separates and recovers the major metals and minerals values contained in municipal incinerator residues (Reference 15). The plant, which can process 1000 lbs. of residue per hour, is sophisticated enough to separate glass into clear and colored components. Based on the engineering data developed, estimates for capital and operating costs for a 1000 ton per day plant show a cost of about $2 per ton of residue. Each ton of residue processed through the plant yields 700 pounds of iron, 40 pounds of nonferrous metals including aluminum, copper, lead, tin, zinc, small amounts of silver and 1000 lbs. of glass. The total value is $10 to $12 per ton of residue.

Automobile tires also present problems. Approximately 180 million tires containing 2 million tons of rubber are scrapped yearly. Incineration of tires causes serious air pollution problems. Disposal in landfills is not desirable because the tires are difficult to compact and are essentially not biodegradable. Bureau of Mines research has shown that the pyrolysis of tires can yield 1500 cubic feet of high-quality gas and 140 gallons of hydrocarbon liquid oil per ton of tires treated. The problem is to make the process economically feasible.

C. The Role of Packaging in Solid Waste (Reference 16)

Since packaging materials is used primarily to convey goods from the manufacturer to user, and since most packages make only a single trip after which they are discarded, packaging plays an important role as a component of solid waste. The $16.2 billion worth of material purchased in 1966 weighed 51.7 million tons. About 90% of these materials was discarded, representing 13.3% of the 350 million tons of residential, commercial, and industrial waste generated in the United States in 1966.

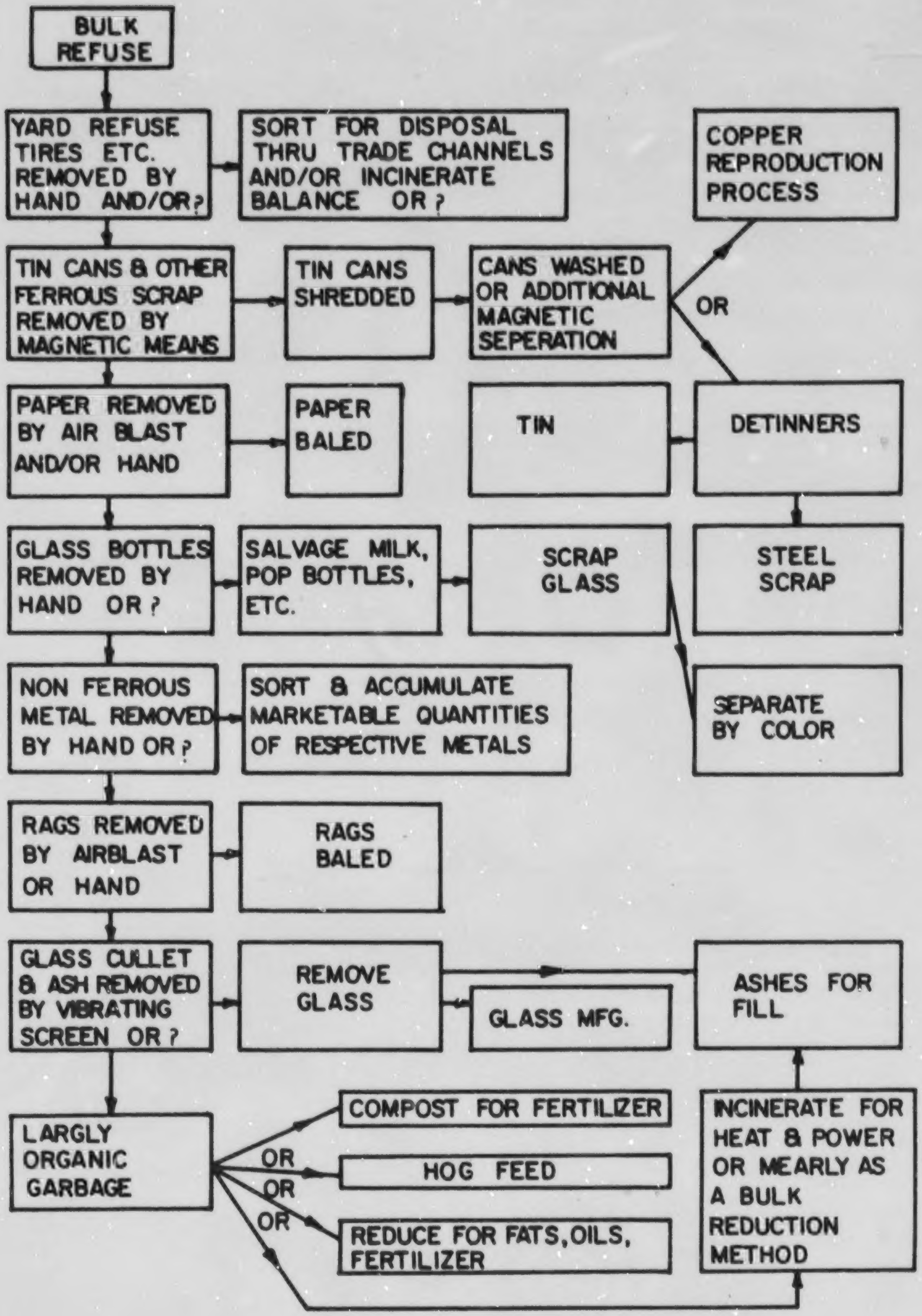
BULK REFUSE
YARD REFUSE TIRES ETC. REMOVED BY HAND AND/OR?
SORT FOR DISPOSAL THRU TRADE CHANNELS AND/OR INCINERATE BALANCE OR?
COPPER REPRODUCTION PROCESS
TIN CANS & OTHER FERROUS SCRAP REMOVED BY MAGNETIC MEANS
TIN CANS SHREDDED
CANS WASHED OR ADDITIONAL MAGNETIC SEPERATION
OR
PAPER REMOVED BY AIR BLAST AND/OR HAND
PAPER BALED
TIN
DETINNERS
GLASS BOTTLES REMOVED BY HAND OR?
SALVAGE MILK, POP BOTTLES, ETC.
SCRAP GLASS
STEEL SCRAP
NON FERROUS METAL REMOVED BY HAND OR?
SORT & ACCUMULATE MARKETABLE QUANTITIES OF RESPECTIVE METALS
SEPARATE BY COLOR
RAGS REMOVED BY AIRBLAST OR HAND
RAGS BALED
GLASS CULLET & ASH REMOVED BY VIBRATING SCREEN OR?
REMOVE GLASS
GLASS MFG.
ASHES FOR FILL
LARGLY ORGANIC GARBAGE
COMPOST FOR FERTILIZER
OR
HOG FEED
OR
OR
REDUCE FOR FATS, OILS, FERTILIZER
INCINERATE FOR HEAT & POWER OR MEARLY AS A BULK REDUCTION METHOD

FIG. 4 FLOW CHART FOR PROCESSING OF REFUSE FOR SALVAGE (ref. 16)

(The 350 million ton figure excludes demolition wastes, scrapped automobiles, agricultural wastes, and mining wastes).

Turning to individual packaging materials, the most significant per capita gains will be made by plastics, paper, glass, and metals, in that order. Wood and textiles will decline. Per capita increases of these materials in the period 1966 to 1976 expressed both in pounds and as a percentage of 1966 weight are shown in the following table.

Material	Per Capita Increase 1966 to 1976 - Pounds	Increase as Percent of 1966 Consumption
Plastic	17.0	152%
Paper	76.6	30
Glass	23.4	28
Metals	3.1	4

The significance of this projection as regards solid waste collection and disposal are:

1. Waste will be more costly to collect per pound because of the lower density.
2. The proportion of difficult to handle materials, expecially plastics, will increase.
3. The amount of land necessary to store and/or process these materials for ultimate disposal will nearly double.

4. The volume of salvageable material in the waste will increase substantially.

One fundamental difficulty connected with collection of package materials falls outside the effective control of the package manufacturer and the disposal agency. That factor is the cooperation of the public in actual disposal of the waste. This can be illustrated by considering the vast difference in difficulty and cost between collecting one ton of cigarrette wrappers discarded in trash containers and one ton of wrappers casually thrown from the window of cars along highways and streets.

Packaging materials apparently constitute a large part of the total litter to be found in the United States. A survey in Kansas along a one mile stretch of a two-land highway listed the following:

770 paper cups
730 empty cigarette packages
590 beer cans
130 pop bottles
120 beer bottles
110 whiskey bottles
90 beer cartons
90 oil cans
20 highway maps
16 empty coffee cans
10 shirts
10 tires
10 burlap bags
4 bumpers
4 shoes - no pairs
2 undershirts

50 paper livestock bags
30 paper cartons
26 magazines
2 comic books
2 bed springs
270 miscellaneous items

Packaging material must sooner or later be disposed of by some sort of deposit on the land, either directly or as a residue from incineration. To help indicate resistance to processing, the following rating tables have been generated.

Rating Definition of Incineration

Rating	Code	Burning Rate	% Inert Residue	1000 BTU/ lb.	% S Content	Potential Damage to Equipment
Excellent	100	Very High	2-5%	12 & Above	.01-.05%	None
Good	200	High	5-10%	10-12	.06-.10	None with proper operation
Fair	300	Slow	10-20%	8-10	.11-.15	Can sometimes disturb systems operation
Poor	400	Self Ext.	20-50	6-8	.16-.20	Seriously disturbs system operation
Satisfactory	500	Nil	50 & above	Below 6	.02 & above	Damage can be considerable

Rating Definitions on Sanitary Landfill

Rating	Code	Natural Density lb./cu. ft.	Compactability	Degradability
Excellent	100	100 & above	Deforms or crushes under pressure and retains compacted form after pressure is released	Item will eventually degrade and disintegrate in soil by bacterial action
Good	200	71-100	Deforms easily but springs back	Item is partially degradable
Fair	300	51-70	Deforms with difficulty	Item will decompose by chemical action
Poor	400	31-50	Deforms but requires special handling in landfill operation	Highly resistant to both bacterial and chemical action
Unsatisfactory	500	30 or less	Not effectively compactable	Virtually indestructible

Rating Definitions of Composting

Rating	Code	Degradability	Handling Suitability
Excellent	100	Degrades quickly	Suitable
Good	200	Degrades slowly	Suitable but requires pulverization or special equipment
Fair	300	Degrades partially	Unsuibtable, but can be removed mechanically
Poor	400	Does not degrade but may be left in compost	Unsuitable, but can be removed mechanically
Unsatisfactory	500	Does not degrade and is an undesirable	Unsuitable and difficult to remove by any means

Rating Definitions of Salvage Reuse and Conversion

Rating	Code	Separability	Market
Excellent	100	Separation is possible by mechanical means	Market exists, little or no preprocessing required
Good	200	Mechanical separation possible supplemented by hand sorting	Market exists, commodity must be sorted
Fair	300	Manual separation required, minimal sorting	Market exists, commodity must be processed
Poor	400	Manual separation, considerable sorting	Market does not exist except possibly via chemical conversion or extensive processing
Unsatisfactory	500	Not practically separable	Market does not exist and is not likely to develop

Disposability Ratings of Major Packaging Materials

Material	Incineration	Sanitary Landfill	Composting	Salvage
Paper	150	160	230	210
Metals	460	170	460	240
Glass	490	160	360	240
Wood	210	270	180	450
Plastics	300	270	480	330
Textiles	190	120	180	250

D. Collection Practice (Reference 9)

The collection and removal of municipal refuse--one of the major problems of American cities--has been given less attention than this essential public function deserves. Only within relatively recent years have most municipal officials been willing to admit that refuse collection technical management is a problem worthy of their attention and study. It should be pointed out that collection and transportation amount to about 75% of the total solid waste disposal bill.

1. Effect of Disposal Methods

The means used to dispose of refuse influence collection practices to such a great extent that the disposal method must be determined and the disposal sites selected before the collection system can be intelligently studied. The size and kind of equipment depend on the length of the haul to the disposal points as well as the type of refuse collected. All too frequently the collection arrangements are made with little or no consideration of the disposal situation. In such cases the cost of the collection method is likely to be much too high.

2. Refuse Variations

The amount and type of refuse generated varies considerably with the seasons of the year. The quantity of garbage in the summer months is contingent upon the problem of long storage. Yard rubbish is most plentiful in spring and fall, although some must be collected throughout the summer. Ashes are normally produced in the cold months. Such variations add to the difficulty of administering refuse collection services. The collection force and number of vehicles must be equal to the peaks. This means that operating procedures must be flexible to permit the work to be conducted economically at all times. Sometimes crews and vehicles can be shifted from one class of collection to another or to some other municipal activity. In other cases the size of the force must be adjusted to the work load. If the size of the force is kept constant, a variation in work hours will be necessary.

3. Collection Methods

There are several methods of getting refuse from the point where householders place it to the collection vehicles. The material may be transferred from regular containers located at curbs or in alleys, full containers may be carried from back doors or basements and the empties returned, full containers may be exchanged for empty ones, disposal refuse bags may be

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used for curb, alley, or back door collection, etc. The technique used affects the time required and therefore the collection cost. Many communities are supplying homeowners with disposal plastic or paper bags which can be used instead of the standard garbage cans. In this way collection is speeded up because a container does not have to be carried back to a yard or alley. In addition collection is quieter than with the can system. The main disadvantages are that the closure of overfilled bags is often faulty and that the bag is an item of solid waste itself.

4. Collection Equipment

Collection equipment is usually selected for reason of economy, sanitation, and appearance. Available are trucks, semi-trailers, container trains, motorized carts, and bodies in a wide range of types, sizes and capacities. The goal is to obtain equipment which is best suited to satisfactorily meet local conditions.

Numerous factors such as loading height, mechanical loading and unloading devices, compacting devices, covers, turning radius, watertightness, automatic drives, and safety devices are important when matching equipment to local needs. Of increasing importance, as more recognition is given to the growing problem of noise pollution, will be noise generated by collection vehicles particularly in the compacting operation.

Under certain circumstances it is uneconomical to transport the refuse to the disposal site in the collection vehicles. If the most suitable collection equipment is not efficient for long hauls, it is well to transfer the collected material to other vehicles. If the disposal area cannot be reached by highway, supplemental transport by rail or water becomes necessary. Consequently, transfer stations must sometimes be provided.

5. Organization

There is no one best plan or oganization for refuse collection. The plan chosen in any particular locality depends on the form of government, size of the community, density of population, kind of service to be rendered, and numerous other factors. What is important is that there is an organization that has taken into consideration the entire system in its makeup and is flexible enough to meet normal variation in a planned manner.

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E. The Solid Waste Disposal Act of 1965 (References 9,17,18)

The Solid Waste Disposal Act was enacted in October 1965. It authorized local, state and federal agencies and private organizations to join in a major effort to rid the nation of health hazards and scenic blight resulting from prevailing practices for disposing of solid wastes. More specifically it authorizes federal action in six areas.

1. It provides up to two-thirds financial support for local and state projects for demonstrating new and improved waste disposal technology.
2. It provices up to two-thirds financial support for the development of area-wide solid waste management systems designed to end fragmentation of disposal responsibility among small communities.
3. It provides up to one-half financial support for state surveys of solid waste requirements and the development of statewide program plans for meeting those requirements.
4. It provides for research work that will form the scientific basis for a new approach to solid waste disposal.
5. It provides for training programs to alleviate critical shortages of qualified personnel.

6. It authorized technical assistance to state and local governments and to industrial and consulting groups.

Many of the reports cited as references here are an outgrowth of this program.

III. STATEMENT OF THE PROBLEM

The basic problem is "applying technology to the unmet needs in the area of solid waste disposal." This includes adaptation of current technology now not being effectively utilized, expanding that technology through pure research and pilot plant development, and of overcoming the major obstacle which is the lack of awareness on the part of governmental decision makers and the public as a whole. Insofar as the course is concerned, the problem is related to the last of these--the lack of awareness. The problem here is to increase the technical literacy where solid waste technology is concerned and to bring about an awareness that technology is available that is not being fully utilized, and that systematic application of that technology as well as increased effort and financial support to expand that technology is vital. Reference 19, which is included as Appendix I, discusses the application of technology to the solid waste disposal problem.

IV. STUDENT ACTIVITIES

Most of the in-laboratory experimentation that came to mind appeared to be "busy work" and of little value in meeting the objectives of the course. It will not be reported here. Student activities that do appear worthwhile include:

A. Presentation of Reports:

A problem exists whereby it is essential that some knowledge of the background material be acquired, yet lecture-type coverage seems out of place. This problem could be approached by assigning different students or teams of students different aspects of the solid waste problem to become "experts" on. These assignments should be made well before the class coverage of the topic and reference material should be available. Students should be cautioned to dwell mostly on objectives, conclusions, and recommendations in the reports and for the most part to only skim the highly technical content. Actual presentation of the material could be improved by having the respective groups attempt to "sell" their particular dispcsal technique for some defined waste situation.

B. Local Visitation and Evaluation

Visits to local government to determine such things as the organization for refuse disposal, the type collection system and disposal system, the quantity of waste collected and the cost of operation might be worthwhile. Visits to disposal sites themselves is another possibility. Also, visits to area industry could be made to determine the source of industrial solid waste and the method of disposal.

C. Decision Trees in Solid Wastes Planning (Reference 20)

This paper describes using probability considerations to deal with chance events in the decision-making associated with solid waste management. Adoption as a classroom exercise should be worthwhile.

D. DISCUS (Reference 21)

DISCUS is a digital computer game dealing with solid waste management decision. It is described in Reference 16 and listings and a card deck are available upon request from the author.

E. Film

An outstanding color movie called "The Third Pollution" sums up in 23 minutes the urgent, too-little-heeded problems of solid-waste management.

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V. REFERENCES

1. __________, "Refuse Collection Practice", American Public Works Association, 1966.

2. Wolf, K.W. and Sosnovsky, C.H., "Rail Transport of Solid Wastes - Interim Report", Grant No. DO1-UI-00073, United States Department of Health, Education and Welfare, 1969.

3. Black, R.J.; Muhich, A.J.; Klee, A.J.; Hickman, H.L.; and Vaughan, R.D., "The National Wastes Survey - An Interim Report", United States Department of Health, Education and Welfare, 1968.

4. Kaiser, E.R., "Refuse Reduction Processes", Proceedings of the Surgon General's Conference on Solid Waste Management for Metropolitan Washington, July 1967, p. 93-104, Public Health Service Publication No. 1729, 1967.

5. __________, "Municipal Refuse Disposal", American Public Works Association, 1966.

6. __________, "Development of Construction and Use Criteria for Sanitary Landfills - An Interim Report", Grant DO1-UI-00046, United States Department of Health, Education, and Welfare, 1969.

7. __________, "Technical - Economic Study of Solid Waste Disposal Needs and Practices", United States Department of Health, Education and Welfare Report SW-7C, 1969.

8. Brunner, D.R. and Keller, D.J., "Sanitary Landfill Design and Operation", United States Environmental Protection Agency Report SW-65ts, 1972.

9. McDonough, P.A.; Peterson, B. and Fritschler, A., "Guidelines for Local Governments on Solid Waste Management", United States Environmental Protection Agency Report SW-17C, 1971.

10. De Maus, J; Keller, D.J., Leckman, J. and Newton, J.L., "Incinerator Guidelines - 1969", Public Health Service Report No. 2012, United States Department of Health, Education and Welfare, 1969.

11. Dial, C.J., "New Technologies in Solid Waste Management", United States Environmental Protection Agency, 1972.

12. __________, "Evaluation of the Melt-Zit High Temperature Incinerator", Grant D01-UI-00076, United States Department of Health, Education and Welfare, 1969.

13. __________, "The Torrax Solid Waste Disposal System", Torrax Syatems, Inc.

14. Wiley, J.S. and Kochtetzky, O.W., "Composting Developments in the United States", Compost Science, Summer 1965, pp. 5-9.

15. Kenahan, C.B., "Solid Waste - Resources Out of Place", Environmental Science and Technology, Volume 5, Number 7, July 1971, pp. 594-600.

16. __________, "The Role of Packaging in Solid Waste", Public Health Service Publication No. 1885, United States Department of Health, Education and Welfare, _________.

17. __________, "Initiating a National Effort to Improve Solid Waste Management", United States Environmental Protection Agency Report SW-14, 1971.

18. Keagy, D.M., "The Federal Solid Waste Demonstration Program", United States Department of Health, Education and Welfare, 1968.

19. __________, "Application Technology to Umet Needs - Report on the Solid Waste Problem", United States Department of Health, Education and Welfare, 1968.

20. Klee, A.J. and Garland, G.A., "Decision Trees in Solid Waste Planning", Public Works Magazine, July 1968.

21. Klee, A.J., "DISCUS - A Solid Waste Management Game", IEEE Tranactions, July 1970.

APPENDIX

APPLYING TECHNOLOGY TO UNMET NEEDS

Appendix Volume V
TECHNOLOGY AND THE AMERICAN ECONOMY,
The Report of the Commission

REPORT ON THE SOLID WASTE PROBLEM

Studies prepared for the National Commission on Technology, Automation, and Economic Progress • February 1966

U.S. DEPARTMENT OF HEALTH, EDUCATION, and WELFARE
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This publication will be distributed to requesters as supplies permit. Requests should be directed to the National Center for Urban and Industrial Health, 222 East Central Parkway, Cincinnati, Ohio 45202.

Report on the Solid Waste Problem

I. Description of the Problem and Issues

Probably the most serious shortcoming in the field of public works since World War II has been a chronic inability to evaluate the status of the art of solid waste disposal and to develop logical and economical systems to meet the changing times. Although some $3 billion are spent annually in the United States to collect and dispose of refuse and other solid wastes, the collection and disposal practices in common usage are but little improved over those of a quarter century ago. Much of the blame must be attributed to the very nature and origin of the problem: Waste disposal has historically been relegated to the lowest levels of responsibility.

It is only too common a practice in all but the largest metropolitan areas in the United States to find solid waste management conducted through a "dirt-under-the-rug" approach. As long as refuse does not pile up in the streets or on the curbs or in the alleys, and as long as the rat-infested dump annoys only the nearby residents, matters of efficiency, economy, public health, and safety are overlooked, and the more "pressing" (and better understood) aspects of community life are studied and financed and programs implemented.

Solid wastes have not been accorded appropriate recognition as a national problem, unlike the liquid waste systems which require thoughtful design and construction, careful operation, and strong public support for generous funding. In the deceptive simplicity of solid waste collection and disposal operations lies the delusion.

Surveys of solid waste collection and disposal practices throughout the Nation reveal very few consistencies. Often the going practices turn out to be the result of cut-and-try techniques handed down from one generation to another. In the Los Angeles metropolitan area, for example, separate collection of food wastes for use as hog food continued for many years after the economic advantage to the communities was grossly outweighed by the far greater costs of making two separate collections. In other cities where outmoded collection service is provided by shoveling refuse from vaults, leaves are pitchforked from loose piles, separate trucks are driven over identical routes to different classes of refuse, and all deposited at the same disposal site, where an expensive incinerator was built on wastelands that could be reclaimed by sanitary landfilling.

II. Technologies That Could Be Applied To Solving the Problem

A. History of Solid Wastes Research

Introduction

Public disinterest in rejected materials has been reflected in a neglect of research in solid wastes management, with the result that problems have multiplied faster than solutions. After World War II the problems of solid wastes management could no longer be ignored, and concern has now reached national proportions. In 1949 the State of California began research which has continued at varying levels of intensity under a variety of sponsors. Similar investigative work was carried on throughout the United States by public agencies.

The early researcher was confronted with a dearth of reliable information on technology and economics of wastes management. When studies of composting of municipal refuse were initiated at the University of California in 1949, literature search turned up some 10,000 references, essentially none of which revealed any scientific understanding of the process or of its utilization in an engineered system. Investigations of incineration showed it to depend upon a technology empirically derived and poorly defined. Sanitary landfilling was found to involve practices of obscure origin and undocumented relevance.

Scope of Research

Research in solid wastes management has been directed to the discovery of basic information, to the development of processes and technology, to the impact of wastes management schemes on the air, water, and land resources, to the economics of collection and disposal, and to jurisdictional and planning problems. While the scope of past research may not be inappropriate, it has been limited by the inadequate scale of research and lack of effort to translate knowledge into effective systems.

Studies have yielded some basic data on the types, amounts, physical characteristics, and origin of refuse. Studies now being conducted by the California State Department of Public Health for the San Francisco Association of Bay Area Governments are producing similar data for the total wastes of metropolitan areas. From such investigations the nature of solid wastes may be established for specific areas, but the climatological and geographical variations from one area to another are so great that such data have only limited general usefulness.

From research on process fundamentals has come knowledge of the principles of composting, the fuel value of refuse, optimum incineration temperatures, the general nature of combustion products, and similar basic data.

Development of Processes and Technology

Investigation and demonstrations of technical feasibility have been conducted for incineration, composting, landfilling, grinding organic wastes with water and discharging the slurry to the sewerage system, and salvage and reclamation, but to different extents and with varied results.

Incineration

University research groups and public agencies have obtained significant information on the design, operation, and instrumentation of an incinerator, including the effectiveness of its various components and the control of its stack effluents. Studies of home incinerators have also been made. While such research has done much to improve the process, such factors as air pollution control, the growing volume of wastes, and the increasing urbanization of the Nation have spurred interest in research and development along the following lines:

1. Improved methods of refuse handling and furnace charging.
2. Determination of stoker and grate performance.
3. Establishing more precise design criteria.
4. Methods of sampling and monitoring incineration process and stack discharges.
5. Mechanical methods of removing fly ash and residue.
6. Control of particulate and gaseous stack discharges.

Composting

Studies of composting at the University of California, Michigan State University, and elsewhere in the early 1950's established the fundamentals of composting. Field scale demonstrations of open-windrow composting were conducted at Oakland and Berkeley, Calif., and mechanized composting was demonstrated at Altoona, Pa.; Norman Okla.; Sacramento and San Fernando, Calif.; and Phoenix, Ariz. Pilot composting plants have been operated at Burbank, Calif., and in Los Angeles. Several other successful and unsuccessful experiments have been conducted in the United States.

Composting combined with sanitary landfilling was demonstrated at Chandler, Ariz., by the U.S. Public Health Service, and application of the process to animal manures, farm wastes, sewage sludge, and cannery wastes have been investigated on a small scale. The National Canners Association, with PHS research grant support, is now operating a pilot plant for composting wastes from fruit and vegetable canning in California.

Investigative work needed to establish composting as an effective process in solid wastes disposal includes:

1. Determination of the market (or lack of market) for compost. Inability to develop markets has been a main cause of failure of composting schemes in the United States.
2. Demonstration projects to refine technical details and establish the economics of composting.
3. Development of equipment and methods for large-scale use of compost in agriculture.

Sanitary Landfill

Research on the sanitary landfill process and related problems has been directed to a variety of objectives. The University of California reported on the methods and techniques utilized by 13 cities and on the economics of landfilling. The American Public Works Association and the American Society of Civil Engineers each prepared manuals of sanitary landfill practice. Management of fills and cover material to prevent the emergence of flies was investigated by the California State Department of Public Health, and the California Water Quality Control Board sponsored studies of the ground water pollution potential of landfills.

Although sanitary landfilling is capable of handling the total solid wastes of a community, its broader application would be intensified by the following investigations:

1. Development of methods for precompacting refuse before placing in the fill.
2. Investigation of construction methods and building design to permit use of completed sanitary landfills for residential and industrial sites.
3. Improvement of methods to incorporate demolition debris in landfills.
4. Investigation of the deposition of compacted refuse in submarine canyons.
5. Development of means for using sanitary landfill at sites having high ground water levels.

Grinding to Sewer

Field-scale studies of shredding organic refuse and discharging it to the sewer have been conducted in southern California. Practical application of the method to a combination of community wastes such as animal manures, paper, garbage, tree trimmings, cannery wastes, plastics, glass, and similar grindable or shreddable materials would require a number of investigative studies, including:

1. Determination of the range of materials which can be water transported in an existing sewer system.
2. Determination of the ability of existing waste water treatment processes to handle shredded refuse materials.
3. Studies of process modifications and extensions, and the economics of adapting existing sewage treatment systems to dispose of water-transported refuse.
4. Studies of feasibility and the materials-handling techniques needed to utilize sanitary sewers as a transport system.
5. Determination of the possibility of converting refuse to particles which might be piped to the ocean and discharged without having floating particles or other pollution.

Salvage and Reclamation

Numerous experiments have been conducted on separation of salvageable materials from mixed refuse. These have been relatively crude, practical attempts to reduce costs to a profitable level, or to develop sophisticated devices, such as magnetic or ballistic separators, to salvage some particular element of refuse.

Experiments on reclamation of selected and limited amounts of certain organic fractions of industrial wastes have developed such products as bone meal, industrial alcohol, vegetable oils, animal feed filler, and wallboard from various components of solid wastes. Economic factors have limited the practical application of these methods. Needed studies in the field of salvage and reclamation are:

1. Methods of isolating salvageable materials before they become mixed into the total refuse.
2. Mechanical methods for rapidly and accurately selecting specific items from refuse; for example, various alloys of brass and aluminum, clear glass, and clean paper.
3. Basic research on the reclamation of reusable raw materials from solid wastes. Determine what compounds can be reclaimed and how reclamation can be accomplished technically and economically.

Reduction in Solid Waste Quantity

Little research has been directed to reducing the volume of solid wastes at the point of origin or disposal. Studies directed to such objectives include:

1. Development of soluble or degradable containers.
2. Improvement of methods of field processing of agricultural products.
3. Development of varieties of foodstuff with minimal waste fraction.
4. Feasibility of legal restrictions on nonreturnable containers, junk mail, etc.

Collection and Hauling

Research on the economic and logistical aspects of refuse handling, including studies made by the University of California which developed procedures by which an economic collection and haul system can be designed. Consulting engineering firms have also made studies for public agencies on both collection systems and equipment, but there is need for an entirely new approach through such avenues as:

1. Application of modern computer techniques and systems analysis to optimize collection systems.
2. Use of existing transport systems, such as public sewers, rapid-transit facilities, etc., for transport of solid wastes.
3. Studies of feasibility of long-distance transport of refuse by highway, railway, and pipeline to remote disposal facilities.

Environmental Resources Management

Air Resources.—The effect of solid wastes disposal on air resources has imposed restraints which require research beyond the relatively simple problem of controlling odors, dust, and fly ash in the immediate locale.

Incineration of solid waste materials results in a significant burden to the atmosphere. Principal attention has been given to the abatement of particulate emissions by internal settling basins or chambers in the incinerator and by particulate collection devices such as cyclones, electrostatic precipitators, and water scrubbers. Much less research has been performed to determine and control the types and quantities of organic gaseous products from the combustion of solid wastes, even though this group of emissions may pose the more serious threat to public health. Organic compounds in gaseous effluent include aldehydes, oxides of nitrogen, organic acids and esters, phenols, and polynuclear hydrocarbons. All cause abnormal physiological responses and some are known to be carcinogenic. Lack of research on the gaseous products, particularly the organics, has been due to inadequate analytical tools and time-consuming analytical processes, but extremely sensitive and relatively rapid methods have recently become available to separate and identify these and other complex compounds.

Specific research needed on the effect of refuse incineration and open burning on the air resource includes:

1. Quantitation of organic emissions in flue gases in relation to type of refuse processed; pertinent operating parameters are yet to be determined.
2. Determination of public health aspects of incinerator emissions.
3. Determination of the fate of organic residues, such as pesticides and herbicides, when agricultural solid wastes are burned.

Water Resources.—Ground water pollution by solid waste disposal has been of concern, especially in areas where water is scarce and ground water forms an important supply. Most research has been directed to effects of landfills on surface and ground waters.

Serious concern has arisen on the question of ground water pollution from landfilled rubbish by two mechanisms: (1) Carriage of water through the refuse and subsequent combination of the "leachate" with ground water, and (2) solution by the ground water of gaseous products of decomposition.

The relationship between refuse disposal and water pollution has been extensively studied in southern California. A 1961 collation study for the State presented the known data on the effects of refuse dumps on ground water quality and delineated additional specific study areas. Subsequent research investigated leaching from sanitary landfills and ash dumps (1953), determined the quantity and quality of gases produced during refuse decomposition (1964), and, currently, factors controlling utilization of sanitary landfill sites. These results showed that little or no impairment of ground water will occur from leaching if the fill is properly located away from intercepting ground water, but gross pollution may occur if ground water intercepts refuse.

Gas movements from a sanitary landfill, methods for controlling and minimizing the passage of gases, primarily CO_2, into the underlying ground are under study. (The solution of CO_2 in water renders the water more acidic, resulting in increased mineralization of ground waters.) It was found that sizable concentrations of CO_2 could be expected to be held in contact with the soil for many years. Field and laboratory research is now directed toward management procedures, such as controlled gas venting and impervious membranes, and development of procedures for minimizing potential CO_2 pollution.

Land Resources.—Solid wastes management, as it relates to land resources, has generated research largely concerned with landfilling processes. Competition for land resources increasingly affects solid wastes management. The State of California is evaluating disposal of solid wastes on the shoreline as a land feature having varied resource values.

Much research is needed in this field:

1. *Resource Planning.* Determine the institutional and legal means of bringing solid wastes and land resource management together at a policy level.

2. *Land Use Planning.* General and specific considerations are:

   a. Local land use studies combined with solid wastes management.
   b. Develop a "land pollution" policy similar to air and water pollution policies.
   c. Need for development of a "problemshed" system of solid waste management.

Jurisdictional Problems.—Any study of local problems in solid wastes management reveals the difficulty of providing adequate management within a framework of uncoordinated and overlapping jurisdictions, each with limited authority and responsibility. A current study in California seeks to apply operations research methodology to develop optimum jurisdictional arrangements for wastes management on a communitywide or regional basis.

Needed research falls into two broad categories:

1. *Legal and Institutional Factors.* A study of public policy, legislation, and institutional arrangements necessary to improve jurisdictional approaches to wastes management.

2. *Systems Analysis.* The application of modern operations research techniques to optimize solid waste disposal systems.

B. Proposals for the Solution of the Problem

Proposals for solving the solid wastes problem originate from three sources: Governmental groups, including local, State, or Federal public health departments, consulting sanitary engineering firms, and solid waste disposal process, equipment, or systems entrepreneurs. Two other groups provide valuable assistance in the study of solid wastes, but they are passive participants in the development of solutions: (1) Universities and technical institutions may study elements of the solid wastes problem, but do not serve as decisionmakers in seeking solutions, (2) professional organizations such as the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Public Works Association, and the Air Pollution Control Association may compile information and circulate technical discussions which assist in the formulation of concepts regarding solid wastes problems. In California, a $100,000 study was made during the summer of 1965 by a private firm, on the concept of "totally integrated waste management," to propose ways and means whereby liquid, gaseous, and solid wastes from the Greater Sacramento area can best be handled. Systems analysis techniques for solution of solid wastes problems have also been studied by the Technological Institute at Northwestern University for several years.

Governmental Agencies

The larger governmental agencies engaged in a "utility-type" enterprise often devote a portion of their funds to research and development but smaller agencies may not be able to engage the necessary engineering specialists and keep them profitably applied to the solution of future problems. From these larger groups have come solutions to solid wastes problems for specific localities, with some applicability elsewhere. Larger metropolitan areas may continue to produce carefully engineered proposals to solve solid wastes problems for their own areas, but nothing short of State or Federal effort will produce proposals for statewide or national application. Tax funds which support a local agency cannot be used to make studies or develop proposals for areas other than those from which the funds were derived.

Some proposals developed and adopted by governmental agencies are relatively successful, but they are not sufficiently comprehensive. In the late 1940's, New York City embarked on a program for disposal of combustible solid wastes which requires 11 large incinerators. These may cost over $90 million before the program is completed in 1968. The program was decided upon when a search for landfill sites failed to reveal enough capacity for a long-range landfilling program. The Los Angeles County Sanitation Districts, on the other hand, found that landfill sites sufficient for 30 or more years existed in the metropolitan area. Much thought was later given to transporting refuse to more remote sites by transferring refuse from collection trucks to large-volume truck trailers. By this technique, since incorporated in the system, solid wastes can be transported up to 50 miles from the metropolitan center to landfills before costs exceed those for incineration. Neither these or similar studies have dealt with the problem of solid wastes collection; about $8 out of $10 spent on solid wastes disposal go for collection; the other $2 are spent on disposal.

Most "comprehensive" solid wastes studies are "disposal" studies, and few studies of the basic problems in solid wastes collection are being undertaken. The California study mentioned earlier deals with refuse collection problems to a limited extent, and the Los Angeles County Sanitation Districts are studying the use of large-diameter sewers for conveying large quantities of ground solid wastes from centrally located grinding stations to sewage treatment plants for removal and treatment by digestion, composting, or wet-combustion. The latter studies to date are encouraging and the economics appear favorable. The Los Angeles County Sanitation Districts are also conducting studies of solid wastes compressibility to develop a suitable system for disposal at sea. The agency is not empowered under the State law to collect solid wastes, consequently it is not conducting collection studies.

The U.S. Public Health Service, through the Division of Environmental Engineering and Food Protection and, more recently, the Office of Solid Wastes, has been instrumental in conducting and encouraging basic research in solid wastes. The Office of Solid Wastes is presently cooperating with the Tennessee Valley Authority in a demonstration of composting municipal refuse and determining its application in an agricultural region.

Commercial Agencies

Proposals for the solution of specific solid wastes problems come from three types of commercial enterprises:

1. Agencies engaged in the manufacture and sale of equipment used in solid wastes collection and disposal.

These agencies include manufacturers of refuse collection trucks, specialized materials-handling vehicles, earthmoving equipment, waste-storage containers, and incinerators. Some manufacturers spend considerable time and money in sales promotion for equipment, systems, and processes. Some use excellent motion pictures and other aids to demonstrate the suitability of their products. Many small communities receive little other information or guidance for their solid wastes problems.

2. Agencies engaged in the marketing of solid-waste disposal processes, usually patented.

The feasibility of these processes may depend upon expected profit or economies such as sale of salvage and end products or reduction in disposal costs. These proposals have two things in common: (1) They depend on careful segregation of solid wastes before or subsequent to collection, and (2) they propose solutions for limited portions of solid wastes and solve nothing with respect to the remainder. Early failure has been all too common. Composting and destructive distillation (carbonization) have been attempted in areas where the market for compost and charcoal has been far below design estimates. Such processes may find their place in the total solid wastes disposal picture, but they are not panaceas.

3. Agencies operating private solid-waste disposal systems.

Contract collection of municipal refuse or solid wastes from markets and industries and the contract disposal of solid wastes are all very much a part of solid-waste practices. Although sewage collection and disposal is almost exclusively a governmental function, solid-waste collection and disposal operations in the United States are divided between private and public agencies. Most major cities in the United States conduct their own municipal solid-waste programs, but there is no pattern for the small communities. By contrast, European practice is almost exclusively governmental. Several cities (Omaha, Phoenix, and Houston) have solicited bids for privately operated solid-waste disposal facilities. The private composting plant at Phoenix has been discontinued and Omaha is reported to have rejected all bids. Houston has let bids for an incinerator and a composting plant and two more compost plant bids are pending. A private firm is building a compost plant at St. Petersburg, Fla., on contract. The public health and safety aspects of solid wastes disposal should receive careful consideration when a determination is being made as to whether a system should be based on profit incentive or upon governmental motivation. Where salvage is involved, private enterprise may be better able to adjust to market fluctuations.

Consulting Sanitary Engineers

Proposals to solve solid wastes problems originate as a statement of the problem by a client; only then is a solution afforded by the consultant. Consulting sanitary engineers will continue to provide solutions to solid wastes problems on specific, local bases. Consulting sanitary engineers are not usually funded to pursue research beyond the needs of their clients, although a limited amount may be necessary for them to remain competitive. Studies by consulting sanitary engineers are usually limited to a single city, but recently several countywide studies have been proposed and at least two have been undertaken. Relatively few sanitary engineering firms make a realistic effort to understand the solid wastes problem, although they have an impressive array of specialized engineering talent. Consulting engineering services have not yet been applied to generalized solutions of the solid-waste problem, perhaps because of the lack of a suitable vehicle to coordinate use of such talent. Many consulting engineers have long shown little interest in the solid wastes field, since for years sewerage and water-supply projects have been the sanitary engineer's "stock-in-trade." Now that solid wastes problems are receiving greater attention, many firms are recognizing the business potential and (rather hopefully) list "solid wastes" as an added specialty. There is a current need for a several-fold increase in consulting service for solid-waste disposal and a rapidly increasing future need. The problem of judging which firms have capability in the solid wastes field is difficult for local officials.

C. Extent That Technology Is Presently Available

The technology of solid wastes management has developed, as have most other technologies, by gradual improvement of equipment and techniques to alleviate problems.

In order to present the current state of the art in solid-waste management rationally, it is necessary to examine solutions in terms of problems.

Solid Waste Production and Initial Handling

Solid waste is produced throughout the world. The problem begins with the gathering of solid wastes for collection and may include separation, bundling, or other types of preparation. This function is usually performed by the producer—the householder or business operator.

A change in this procedure is the use of garbage grinders. This change was due to householder demand for added convenience and sales ingenuity on the part of manufacturers. This has demonstrated that the householder may be willing to make the required capital investment for refuse disposal. Similar changes may support converting even greater fractions of solid wastes into the liquid-waste management systems.

Collection Systems

In urbanized society, collection vehicles are periodically sent through the neighborhood, gathering accumulated wastes. Motorized heavy equipment now allows greater loads to be carried by each vehicle, and emptying refuse is much more convenient. Increased vehicle capacity, specialization, and range permits selection of remote disposal sites.

Time and motion studies have been made to determine whether refuse should be stored and picked up at the rear of the house or whether the householder should place refuse at the curb for collection. Studies have also been conducted on the separation of salvageable items at the point of origin so that salvage would help defray the cost of refuse disposal. New systems of magnetic and ballistic separation, subsequent to collection, are presently being investigated and operated on a limited scale.

Transportation

Vehicles designed for collecting refuse are not suitable for transporting refuse any great distance. The specialized nature of the loading and packing devices on collection vehicles increases their cost, and it is not good economy to have them out of collection service during long hauls to the disposal site. For this reason, refuse transfer stations, where the collection vehicles are unloaded into large-capacity trucks for bulk delivery of refuse to the disposal site, have become economically feasible. Systems-optimization analyses of collection and transportation schemes are helpful in designing such systems to meet the wide variety of local conditions which influence the total cost of transportation and disposal.

Disposal Systems

Disposal systems may be of two types: (1) Disposal without provision for salvage or energy recovery; and (2) disposal with partial, or nearly complete, recovery of salvageable material and/or energy.

Disposal Without Material or Energy Recovery

The following disposal methods are in common use in the United States:

1. Open dumps.
2. Sanitary landfills.
3. Central incineration.[1]
4. On-site incineration.

Open Dumps. Open dumps, although common in the United States, cause a variety of difficulties, including the production of rodents, mosquitos, fires, and odors, and are unsightly and offensive to nearby residents. Sanitary landfills can replace dumps at relatively small additional expense. As the welfare of the country's smaller towns improves, open dumps may be eliminated with only slight prodding on the part of public health and public works agencies.

Sanitary Landfills. A sanitary landfill is an engineered burial of solid wastes. The problems common to open dumping do not develop. The technology of sanitary landfills has been improved by research to determine such factors as the depth of compacted earth cover required to prevent insect, rodent, and other vector infestations; the dangers of leachate reaching and contaminating ground water; the amounts and types of gas production and movement within the soil; the rate of settlement, and many other features. A sanitary landfill can be a very desirable asset in a community since, when completed, the site can be used for such purposes as recreation and parking or light construction.[2] An excellent sanitary landfill may be conducted for a total cost of approximately $1 per ton of refuse disposed (including amortization of land costs). Problems such as underground fires and dust nuisances created during construction result from careless operation and are easily minimized by careful management.

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[1] Technically speaking, there are a few instances where energy is recovered heat. This represents a very small fraction of the total energy available.

Municipal Incineration. Many U.S. communities, particularly the larger ones, use municipal incinerators to reduce the volume of solid wastes. Noncombustibles are either collected separately or passed through the furnace along with the other refuse. Magnetic devices may be used to separate ferrous metal from the ashes for salvage. Incineration reduces the rate at which land is used by one-half to a third of that required for sanitary landfilling. The operating cost of large-scale incinerators generally runs from $4 to $5 per ton, including ash-disposal costs.

Since transfer stations can be built and the waste transported to landfills up to 50 miles distant at a total cost of less than $5 per ton, a community should seriously consider such systems as competitive with incineration, if suitable landfill sites are available within this distance.

No current municipal incinerators are considered acceptable where climatological conditions create severe smog concentrations. Conventional designs can be used only at low (half normal) charging rates if Los Angeles' incinerator standards are to be met. Although the incinerators may be equipped with electrostatic precipitators to control particulate emissions, either of these alternatives increases incineration costs by an additional $6 to $8 per ton.

Incinerator equipment manufacturers are developing improved furnace equipment. Publications on this subject represent perhaps one-half the literature available in solid-waste disposal.

Onsite Incineration. Incinerators for effective disposal of combustible solid waste in the home and for apartment buildings and small business or commercial establishments, offer great promise for reducing the volume of solid wastes at the source. Present designs are generally inadequate and such incinerators contribute significantly to air pollution. Additional research, development, and demonstration are needed before this form of onsite incineration can be effectively applied to the solution of solid-waste disposal problems. Some communities still permit backyard burning of refuse as an onsite disposal method. This inefficient process invariably produces smoke problems. It remains in use in isolated communities and rural areas, but poses serious problems.

Other Methods. Municipal refuse has been disposed of at sea, but remnants drift back to shore and this method of disposal is not being used on any substantial scale in the United States. It may have potentials if solid wastes can be processed so as to cause them to sink to and remain on the ocean floor.

Disposal With Material or Energy Reclamation

The following methods are in use, or have been used, to dispose of waste and to salvage material and energy:

1. Grinding garbage to the sewers.
2. Feeding wastes to swine.
3. Fertilizer production.

Ground Garbage to the Sewers. When garbage is ground and discharged to the sewer, most of it is treated in the treatment plant's digesters. Additional methane which is produced by the digesters can be used as a supplemental or primary source of fuel. Digested sludge may be dried and used as a low-grade fertilizer or soil conditioner.

Research has been conducted on the effects of varying amounts of cellulose in sewage sludge and its effects on anaerobic digestion. This research indicates that much of the paper (cellulose) fraction of refuse might also be amenable to digestion and hence, if it could be shredded and deposited in the system, it would present little problem and considerable potential to the production of methane gas (increased digester capacity would of course be required).

Feeding Wastes to Swine. In the past, many cities disposed of garbage by feeding it to swine. To prevent the spread of vesicular exanthema in hogs, and trichinosis in humans, laws were enacted to require that garbage be sterilized by cooking before it could be fed to animals. Where widespread use of household garbage grinders has reduced the amount of garbage and where the costs and inconvenience of separate garbage collection are excessive, feeding of garbage to swine has declined.

Organic commercial wastes and restaurant and institutional garbage are sometimes still fed to swine, since such wastes are amenable to cooking.

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[2] In a few cases where land values have increased phenomenally it has become possible to construct the necessary foundations to make building on fills a practicality.

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Fertilizer Production. Composted refuse has some fertilizer and soil conditioner potentials. Composting is widely practiced in Europe, since European agricultural practices have long used manures and composts and there is an established market for compost. The U.S. market for compost does not appear as favorable.

Composting ventures have failed in this country, except for a few relatively small plants.

To help evaluate the overall market for commercial organic mulch, it may be noted that dairy manure in Los Angeles has a value of a negative $2 a ton f.o.b. the dairy and in Arizona the value of steer manure is zero and is dropping.

An integral part of composting is the separation of metals, rags, and glass from the refuse; presently the salvage value of these materials is barely sufficient to pay for the cost of separation.

III. Obstacles to Solution

A major obstacle to the solution of solid wastes problems is the lack of an awareness on the part of governmental decisionmakers that the problem even exists. This lack of awareness exists at all levels, including the mayors and councilmen of cities, county supervisors, State administrations, and, until recently, at the Federal level. The Solid Waste Disposal Act, Public Law 89–272, enacted late in 1965, marks a new awareness at the Federal level. The Office of Solid Wastes has been established within the Public Health Service to carry out the comprehensive program authorized by this legislation. At a study conference held at Cincinnati in 1964, some 30 solid wastes specialists stated unequivocally that the most pressing need in the solid wastes field is for a concerted effort by the Federal Government to make top-level officials at the State, county, and local government levels aware that a serious national problem exists in disposing of solid wastes. The study group also recommended a number of 1-day or 2-day informational courses to be held regionally by the Public Health Service, to be followed by a national conference on solid wastes to dramatize the problem and provide news and information media with information on the scope of problems and the fundamentals of solid wastes management.

Technological Obstacles

Presently accepted practices for solid wastes collection and disposal have been little changed: Collection vehicles usually turn out to be slightly improved copies of last year's models—except for a modest "breakthrough" occasionally such as the one-man right-hand drive vehicles being tested on the West Coast. Incinerators are not greatly changed, but refractories and internal equipment are gradually being improved. Sanitary landfilling is refined to the degree that it is an acceptable practice in Los Angeles County, even when conducted close to $125,000 homes.

Composting has been researched so that there now are a number of documented processes that produce acceptable compost from solid wastes. The technological obstacles do not lie in failure to understand the currently used processes; they lie in a failure to develop new or improved alternatives. Even systems analysis becomes useless when existing systems have been refined by trial and error methods until very little refinements can be made, even by rigorous mathematical treatment. Technological obstacles to the solution of the solid wastes problem are found at the most basic level of the system; i.e., the entire "hardware" structure is based upon refinements of simple techniques that have been little changed for many years.

As an example, a cursory consideration of the megalopolitan developments occurring in major cities indicates that present-day "onsite" storage of refuse is not appropriate for multiple dwellings. Special incinerators, collection, and storage systems have become essential. A piped pneumatic collection system for sewage and solid wastes might be feasible. In the Garchey system, solid or semisolid wastes, including cans, bottles, paper, garbage, sewage, rags, etc., are all conveyed to a central holding tank for collection by special trucks and subsequent treatment by burial or composting. Technology in the field of solid wastes systems for intensely developed communities in the United States is generally inadequate.

Obstacles Created by the Vested Interests of Existing Institutions

The interests most likely to present obstacles to changes in the field of solid wastes may include equipment manufacturers, salvage process owners and patent holders, operating agencies, and some consulting and public works engineers.

Equipment manufacturers have the most to lose in any major technological breakthrough. Developmental costs on specialized refuse collection and solid industrial waste collection vehicles are substantial, and the annual purchase of collection vehicles is estimated to be between $75 and $100 million. New developments are unlikely to affect the economy of this industry for a decade or more, but reductions in vehicle collection of solid wastes probably would be resisted.

Salvage process owners and patent holders are directly affected by changes in public policy on solid wastes management. A large salvage firm in Los Angeles almost ceased operations after the city discontinued separate collection of metal. Patent holders in composting, destructive distillation, or other such salvage operations will surely resist solid wastes systems that exclude application of their processes.

Private companies in the solid wastes collection field will most likely object to any changes that would transfer the operation to the use of municipal sewers and sewage treatment plants before their existing disposal sites were filled to capacity.

Engineers, both public and private, have vested interests in the techniques that they know best. Incinerator specialists, composting experts, transportation consultants, and others may find that changes in technology would require retraining and perhaps temporary economic dislocation as new ideas are developed and adopted.

Obstacles Created by Market Considerations

If the experience developed through the sale and use of kitchen food-waste grinders is an indication of the market acceptance of new and improved solid wastes systems in general, the public can be expected to pay a reasonable cost for convenience; the cost to the householder for owning, using, and replacing garbage grinders averages about $0.75 to $1 a month. Since many municipalities provide weekly pickup of *all* refuse at the curbs, there is little profit to the homeowner in operating his own garbage grinder. How successfully other forms of solid waste can be disposed of without home storage and truck collection remains to be seen. Costs to the homeowner for such service may well be greater than present-day costs. More important, present-day collection and disposal techniques may not meet the standards we are setting for future urban and metropolitan development. History suggests that people will demand the best service their technologists can provide them, if the cost is within reason.

Political Obstacles

Without a plan having as a basic element State and interstate planning and cooperation among local jurisdictions, the fragmented activities and uneconomic duplication of disposal facilities will continue. Although the county is frequently the most logical unit of local government to provide solid-waste disposal services, only 10 States have laws which provide their counties with the enabling legal authority and the administrative tools needed to carry out the work. Where metropolitan areas cover parts of several counties, other operating disposal agencies will have to be devised and organized to provide the advantages of areawide planning, disposal service, and economy of scale. An example of fragmented jurisdiction within the total urban-surburban-agricultural complex that constitutes a modern community is the San Francisco Bay area. Here there are 88 agencies responsible for solid-waste disposal, each seeking to dispose of its refuse in the other's backyard at 77 separate sites.

IV. Recommendations

1. Alert decisionmaking public administrators throughout the Nation to the serious nature of the solid wastes disposal dilemma. This could be accomplished in a number of ways, e.g., by a series of regional 1-day conferences to reach the local levels of solid wastes management responsibility. These conferences may reasonably continue for additional days to meet the training needs of public works officials and supervisory employees.

2. Enhance efforts toward national recognition of the solid wastes problem through support of a national conference on solid wastes management. This would encourage news media to alert the general public to support long-range planning, research, and development efforts.

3. Support full implementation of Public Law 89–272, the Solid Waste Disposal Act, which provides funds for needed research, demonstrations, training, surveys, and planning in all aspects of solid-waste handling, particularly to develop new and improved methods of solid-waste disposal for urban, suburban, and related industrial operations. Review effects of this legislation to determine if any changes are desirable after the first year of operation.

4. Encourage a comprehensive study of the market for salvaged solid wastes (or energy therefrom) as an economic guide to the feasibility of composting, destructive distillation (carbonization), incinerator waste-heat recovery, metal recovery (as from car bodies), glass recovery, and fiber recovery. No valid estimate of the true economic role of an individual salvage process can be made until such broad market surveys are completed.

5. Encourage research directed to the development of completely new systems of solid wastes collection and disposal.

6. Conduct research and development aimed at reducing air and water pollution and solid wastes into basic residues, taking into consideration such reductions as may be possible through reuse potentials. Conduct demonstrations in experimental regional environmental designs which incorporate residue management systems.

7. Review the effect of recent Federal solid-waste legislation to determine if any changes are desirable after the first year of the program.

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DATA TECHNOLOGY - - - - A POLLUTANT?

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DATA TECHNOLOGY - - - - A POLLUTANT?

This is a module of instruction which is designed to be included in a course about science and technology for the non-science student. The objective of the module is to make the student aware of a specific technology, the reason for its development, and the effects.

The underlying discussion and presentation is conceptual, thus no previous knowledge is needed nor any special equipment. The module develops the need and origin of data, the conceptual specifications of the technology and the effects on the individual and society.

BACKGROUND INFORMATION

The time is 3 A.M. The day is July 16. The temperature is 70°. The weather is clear. The wind is from the South-West at 7 mph. A chemical plant located 30 miles south-west of a large metropolitan area has just developed a crack in its air filtering process. As a result, a gas is being released and is escaping at a rate which will cause anyone who inhales this polluted air to be immediately and dangerously afflicted. This pollutant is non-odorus and heavy, remaining for a long period of time without dilution.

The chemical plant operating supervisor becomes aware of the leak at 4 A.M. and bypasses the faulty air filter to a stand-by unit. An inspection of the damaged filter does not reveal if a pollutant may have escaped. He notes the occurrence in the operating log so that the filter may be repaired.

Seven miles away in the direct path of the wind from the chemical plant a small van, several strange looking projections spin around like radar screens. At 4:01 A.M. a typewriter device at the Air Emergency Office of the National Environmental Control Center, located some 300 miles from the large city, starts typing and at the same time a loud alarm sounds. The night operator goes to the typewriter, pauses to read the message, and immediately calls the afflicted area Emergency Air Pollutant Control Center which has stand-by aircraft ready on-line. These aircraft are in the air by 4:15, seeding the path of the air pollutant with a neutralizer.

This short fictitious story could very well be true. The human night supervisor performed what he could do given the facts. The van also performed what it was to do given the facts. The night operator at the Air Emergency Center did what he did, given the facts, and the Air Pollution Control Center did what it was to do, given the facts.

That is what data technology is all about - gathering, manipulating, and disseminating information. The van had special air pollutant sensors taking readings every minute (gathering); the readings were tranmitted to a small computer in the van which compared these readings to previous readings and to standard norms determining a dangerous situation (manipulating); then the computer 'called' the Air Emergency Center informing the center of the situation (dissemination).

Without the technology, it is conceivable that a disaster may have occurred. The situation as described is almost beyond human control. The ability of humans to manually sample the air, perform analysis, and determine a trend every minute without error and without tiring is almost impossible. The massive amount of facts which occur every minute is staggering.

From a commercial view, a corollary situation is the record keeping of checks. Over 2 billion checks are handled in one year. The checks must be collected by the bank, an adjustment made to the records, comparison made on the balance, and the determination of how the check should be handled. A tedious task, collecting, processing, and distributing checks not suited to humans.

Again, data technology has fulfilled this vital function. Machines have been developed which sort the checks and distribute them to the correct bank, computers which perform the bookkeeping, and printers which disseminate the balances.

Data technology has a Dr. Jekyll-Mr. Hyde character just as most technologies. The ability to collect minute details of enormous magnitudes, process it, and disseminate it can be viewed as the advent of 1984. Data technology misused or mistakenly used, poses a serious threat to man and society.

The effects of data technology on man can be viewed from two positions. A positive view would be the release from menial tasks, a negative view would be the haunting aspect of knowing that every action is being observed and recorded. On society, a positive view would be its ability to assist in maintaining and improving its health, a negative view would be the fear of society to congregate or speak.

Again, like most technologies, its threat is not recognized until sometimes it is too late. Unlike most technologies, the threat is so subtle, the effects so unconsciously felt, that it is even more important to recognize the dangers. Webster's 7th New Collegiate Dictionary defines POLLUTE as:

1. to make ceremonially or morally impure: DEFILE.
2. to make physically impure or unclean: BEFOUL, DIRTY, TAINT.

Synonym is contaminate.

The definition of pollute with the potential dangerous aspect of data technology raises the question that it may very well be considered a pollutant. If so, then it must be recognized and its use controlled. However, at this time few people consider it dangerous because few people are consciously aware of it.

To become aware of data technology and its use, one must conceptually understand certain words and their usage. The starting point is finely differentiating between three words --- fact, data, information. A fact is a specific happening, an act or a thing done. To describe a fact, it must have relative identification such as time, measurement, frequency of occurrence. Some facts are continuous, never separating in any instances in time; some are discrete, measurable and separable. Regardless, the number of facts occurring in any instant in time, from chemical reactions to births and deaths, are very large approaching infinity.

A fact, however, is meaningless unless it is recorded, so that at a later time it may be used by itself or with other recorded facts. The recording of a fact brings to usage another word - data. Data then is a recorded fact. This causes a priority as to what facts will be recorded, which will not. The infinite number of facts occurring means some selective process must be used to convert them into data. When recorded, the fact must be given reference - identification. This further complicates the recording introducing inaccuracies and absence of certain references. At the same time, identifying the fact, also dictates the method of recording the fact, therefore, the data. Data gathering (fact recording) required in most cases, whether scientific or commercial data technology.

The technology developed to automatically detect facts as they occur is called source data automation. It ranges from sensors which transmit signals to a central location to magnetic ink character recognition equipment which magnetizes the preprinted numerals on checks and 'senses' their numeric meaning. Once the data has been detected, it must be recorded.

Several types of technologies to store the data have been developed. Regardless of how data is actually stored, the important point is how the data is organized and retrieved. Data can be stored by ordering it on one of the facts identifiers, such as chemical components or checking account numbers, and placing the data in a consecutive order. Or data can be stored with no apparent order but its location can be determined by an index or formula thus providing for a method of retrieving.

Once the fact is recorded, it can then be processed in some manner which will make it meaningful. If it is not processed nor ever used in its raw form, the fact remains data. By processing it and having it used by man, the data provides information. Information then is data which has been used in meaningful manner. The word meaningful does not imply usefulness or correctness. This is where data and its technology may become a pollutant.

The technology which supports the functions of fact to data to information is a system of devices. With source data automation technology the data can be gathered without manual intervention. With computing technology, which can process data in nanoseconds, the three can be tied together to provide information in seconds.

Data needs to be stored and accessible to computers. Another example of technology is termed mass storage devices. These devices hold millions of characters which identify the facts.

This equipment is the necessary backbone of data technology capabilities. Two devices in popular use is the disk and tape mechanisms. The disk provides for immediate access to data, where as tape provides for greater storage capacity. These two devices can be compared to a phonograph and a tape recorder. Assembling the technology into a system can provide information to end-users, persons or other technological systems, over and over at fractions of a second.

These systems of data technology have provided great benefits to man and society. An example is the automatic reservation system allowing one to travel without regard to hotel and transportation problems. Multiphasic health testing centers as mentioned in TMMW is an example of the benefit to society.

These systems of data technology can also be detrimental to man and society. If a person's facts are mixed with anothers, it is possible to cause great personal harm such as rejection of credits. Society conformity, necessary for maximum utilization of data technology systems, can suppress creative thought and action.

The effectiveness of data technology, it being able to do things for man and society which never could be done before, has pushed for more and more systems. Government and commerce are calling upon more installation of the systems. Their justification is effectiveness. But effectiveness is only one consideration. The mass of data being assembled and just now being processed has also the potential of polluting our society by the invasion of the individual's right to privacy.

ACTIVITY #1 - IDENTIFYING FACTS

Notes to the Instructor - This activity is needed to get a common agreement to the word "fact", to generate an awareness of facts, to get a feeling for the number of different facts, and to get a feeling for frequency of a fact in time and space. The instructional method is to present a definition or concept, present an example, and to have the students apply.

Instructional Objective - to make the student aware of what a fact is, of different types of facts, and the frequency of facts.

Instructional Method

1. Present a formal definition of the word "fact" - an act, a thing done. An act or a thing done, maybe thought of an an incident, an occurrence, a transaction
2. Present an example such as
   "The carbon monoxide was 10 ppm at air pollution monitor station #3 at 4:00 p.m. on July 4"
3. Present the concept of relative identification - a fact must have material substance, and for the human it must be perceived by the senses. It must be able to be described by its concreteness, that is, it must be able to be specified. It is identified by its measured relation to other facts.
4. Present step 3 by referring to example in 2.
   "10 ppm at air pollution monitor station #3 at 4:00 p.m. on July 4"
5. At this time have the student list 10 facts with identification. After a short time - possibly 5 minutes - have one student list these facts on the blackboard.
6. Lead discussion to examine whether these are facts, and to stress the wide number and variety of facts.
7. Present the concept of frequency - facts which have the same relative measurements over time and/or space may be counted to determine the rate of occurrence.

8. Present an example of frequency both with respect to time and space. Such as in step 2. If these measurements of ppm were counted over time, say 10 minutes with one measurement noted per minute, then the frequency of 10 ppm may be noted 6 times, 12 ppm 4 times. Or in the case of space, at the 10 monitor stations the frequency of 10 ppm was observed 4 times, 12 ppm 6 times.

9. At this time the student should refer to his list to determine how frequency can be noted for his facts.

10. Lead a short discussion as to methods of determining frequency, and how these facts can be seen to be large magnitudes of occurrence.

11. Assign the student to take one of his facts (or one more within his ability), determine a frequency according to his activity in step 9.

Measurement of Instructional Objective

1. Given 5 minutes, the student will list 5 facts, their identifiers, and the type of frequency that would best measure their occurrence.

Supplies/Equipment - Handout of definition and concepts.

Other Notes - The students will likely list facts which are more sociological rather than scientific. This is all right as it is the awareness of facts and frequencies, note types of facts this session is designed for.

HANDOUT -

fact - is an act, a thing done. An act or a thing done may be thought of as an incidnet, an occurrence, a transaction.

identifying a fact - a fact must have material substance, and for the human it must be perceived by the senses. It must be able to be described by its concreteness, that is it must be able to be specified. It is identified by its measured relation to other facts.

frequency - facts which have the same relative measurements over time and/or space may be counted to determine rate of occurrence.

ACTIVITY #2 - WHICH FACTS SHOULD BE GATHERED

Notes to the Instructor - Any endeavor, be it scientific, sociological, whatever, has a large appetite for facts. Each though, must compromise as to the number of different facts it will use or else it would be "swamped". Thus priorities, sometimes objective - sometimes subjective, are assigned to various facts.

Instructional Objective - to make the student aware of the potential swamping effects, the need for priorities, the selection of a limited number of facts.

Instructional Methods

1. Review the assignment from step 11 of Student Activity #1. Was the student able to determine a frequency? (This is important now, and later, to develop the feeling for frequency and the magnitude of the number of facts. Technology, as developed later, will be more appreciated).

2. Using the discussion resulting from step #1 lead into and discuss the "swamping" effect.

3. Present an example - such as the number of different facts which could be obtained in a chemical/physical analysis of air in air pollution monitoring, and the number of readings which could be taken of each.

4. Have the student take any endeavor and have him list the facts which could be useful if gathered on a blackboard. (See other notes).

5. Have one student present his facts and challenge the class to develop that many more.

6. Present the need for assigning priorities to select those facts which must be gathered to those which are nice to know. Priorities could be set up by group classification or by individual classification. The method varies from situation to situation.

7. Present an example - such as in step #3. Several facts were presented, but by taking various positions the priorities for the facts change. If the purpose is to measure pollution over an expressway the CO could be given a prime priority. If the purpose is to measure pollution over a large body of water some other fact would be given a prime priority.

8. Have the students take one position, his choice, and assign priority.

9. Lead a discussion in what his position is and his choices. Point this discussion to what is subjective priority vs. an objective priority.

10. Assign the student to interview another member of the faculty or administrator to determine the facts they would want, and to establish a list of priorities.

Measurement of Instructional Objective

1. Given "Ralph Nader" and the automobile, list 20 facts which would be needed to determine the safety of an automobile. Assign priorities from his view point.

Other Notes - The student will not likely list too many facts in #4. This is understandable because of his limited exposure. By moving to #5 this should help each student see his own limited view point and also how easy it is to develop these "needed" facts. The assignment could be a difficult one to accomplish if the next class meets very close to this present one. Allow enough time, depending on the number of students, etc.

ACTIVITY #3 - FACT TYPES, IDENTIFIERS, INACCURACIES

Notes to the Instructors - Facts come in two types - discrete and continuous. Scientific facts are usually continuous where as Sociological facts are discrete. Regardless of type, facts when recorded are usually in the discrete form. When recorded they must be given reference-idenfifiers. The conversion of continuous facts to discrete and the identifiers both lead to inaccuracies in data.

Instructional Objective - to develop the students ability to recognize types of facts, to determine proper identifiers, and to be aware of inaccuracies.

Instructional Methods

1. Review assignment from step 10 - activity #2. Lead a discussion into the facts which the student was able to determine and the priorities. This is important for a later presentation.
2. Present the concept of continuous facts and what must be done to capture them.
3. Present an example such as the measurement of CO as before. Question the group as to whether it was representative.
4. Have the student determine what was a continuous fact in their lists.
5. Pick one fact and ask how it was noted, that is recorded - again seek out the problem of identifiers.
6. Lead a discussion on what kinds of identifiers are needed for types of facts for different persons.
7. An example to be presented might be again the CO example. It was given time, place, and measurement. Take another example such as the fact of a hamburger being bought - here time, place, measurement are again important.
8. Have students examine their lists to come up with more identifiers.

9. Lead a discussion on how accurate the identifiers must be. That is the example concerning the hamburger need not be accurate as to time, but most certainly place and measurement.

10. Assign students to review their lists of facts and identifiers to determine accuracy, and to discuss the consequences of a fact and/or identifier which is not as accurate as it should be.

Measurement of Instructional Objective - Given 5 facts and identifiers, the student will determine the type, the accuracy needed, the probable consequence of an inaccuracy.

Other Notes - This activity is designed to assist in having the student determine methods of gathering facts (next activity) and to develop an awareness of inaccuracies which is needed at the end of this module.

ACTIVITY #4 - GATHERING DATA

Notes to the Instructor - The types of facts dictate the method of gathering data. Continuous facts may be gathered by sampling techniques or by a continuous recording. Discrete facts must be gathered by sampling or by a discrete recording of each fact. The needed accuracy also determines the method. In addition, the identifiers may cause the choice of the method. All these serve to select the gathering method.

Instructional Objective - the student will be aware that different gathering methods are selected depending on type of fact, identifiers, and accuracy.

Instructional Method

1. Review assignment step #10 - activity 3. The selection of identifiers, facts, and inaccuracies lead to choice of gathering methods.
2. Present continuous facts, their identifiers, accuracy.
3. An example might be CO if it reaches 40 ppm. This might cause an alarm to go off if it continues for 10 minutes. The continuous recording would be necessary.
4. Select facts students have noted as continuous and lead to discussions to methods of gathering data.
5. Present discrete facts, identifiers, inaccuracies.
6. Select facts students have noted as discrete, lead discussion of methods of gathering data.
7. Example might be the hamburger purchase. Gathering each purchase causes "swamping", however, measurement of tons in and out plus standard weight would be enough to determine purchase number.

Measurement of Instructional Objective

Given 10 facts, identifiers, and inaccuracies, the student will select gathering method and write a short justification of choice.

Other Notes - Obviously the method of gathering facts chosen by students is sometimes impossible or impractical. This should not be discouraged, because in the next activity this is discussed.

ACTIVITY #5 - PROBLEMS OF MANUAL DATA GATHERING

Notes to the Instructor - This activity is designed to identify the problems with gathering data. One problem is that some choices of gathering data preclude manual recording; for example, data which might be gathered in very short time intervals. Another problem is volume, in that the mass of data is beyond manual recording. Another problem is that some data just can't be recorded because the technology has not been developed.

Instructional Objective - the student will be aware of data which cannot be gathered manually

Instructional Method

1. Demonstrate conceptually how a sample of air would be analyzed.
2. Lead a discussion concerning how inadequate this would be for controlling stack emission.
3. Have the students review their lists of facts, and gathering methods for those items which would not be capable of manual recording.
4. Present the magnitude of facts. That is an air pollution station reading 15 facts every minute times 60 minutes times say 15 stations.
5. Demonstrate this problem by having 5 students representing a monitor station read 16 facts every minute. The remaining students are to listen and write down these facts. (This will require some coordination).
6. Present the problem of capturing data in a nuclear reaction.
7. Have the students review their lists to determine which might be difficult to gather.

Measurement of Instructional Objective

1. Given 5 facts, with methods of gathering data, the student will determine which facts can be manually recorded and which can not.

ACTIVITY #6 - DATA STORAGE

Notes to the Instructor - The last activity demonstrated the problem with gathering data. This activity concentrates on ways which will hold the data which can be recorded, and how this way of storage will influence its possible use as information.

Instructional Objective - the student will be aware of two ways in which data can be stored.

Instructional Method

1. Choose a fact which lends itself to being recorded manually. An example might be the mercury content of fish. The technology for this measurement has not developed to allow a "real-time" measurement of live fish. This gathering method lends itself to manual recording.
2. Have the students select those items in their list of facts which could be gathered and recorded manually.
3. Present a short demonstration of the two ways data could be recorded - on 3x5 cards or a roll of paper. Lead a discussion of the advantages of each - cards allow for rearrangement, or for going directly to it, the roll allows for compact storage, original continuity and holds together.
4. Lead a discussion about the problems associated with the various ways. That is the problem of sequential storage (roll) versus direct access storage (cards).

Measurement of Instructional Objective - The student, given a set of facts will select a way of recording which will serve him to the best advantage.

Other Notes - This objective is needed later when secondary storage is discussed.

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ACTIVITY #7 - PROCESSING DATA

Notes to the Instructor - This activity is designed to develop an awareness of how data may be processed. Only three methods are chosen - the single piece of data, the summarization of data, the collection and merging of apparently unrelated data.

Instructional Objective - to make the student aware of three data processes

Instructional Method

1. Present the concept of data, one recorded fact, which would be of importance without any processing. An example might be a reading on the Richter Scale.
2. Have the students identify from their lists which data by itself is important.
3. Present the concept of summarization of data. An example might be the summing and averaging of CO readings for an hour.
4. Have the students choose those items from their list which could be processed in this manner.
5. Present the concept of collecting and merging unrelated data. An example might be the measurement of BOD in water supply at one point of the river, and "fish kill" at a farther down river point. The point of this example is that a water pollution station gathering its readings would be gathered and saved by one method, the observation of the "fish kill" by another, but the relation of BOD may explain the other.
6. The students should observe their lists to determine if two unrelated data could be assembled for more meaningful information.
7. Arrange the class into a seating arrangement which forms an "X". At each of the outer points of the X give each student one different sentence of a four sentence paragraph. Have them whisper it to the next person in line. The game is to see if the center person can assemble the paragraph. This activity demonstrates two points; the problem of communication and the problem of processing.

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Measurement of Instructional Objective - Given 4 apparently unrelated facts, identify one which needs no processing, one which could be "average", and two which would be important if merged together.

Other Notes - This activity sets one of the most important points of this module; the assembling of unrelated data to form a meaning. If students cannot find any data in #7 which could be related, this is understandable.

ACTIVITY #8 - DELIVERY OF DATA

Notes to the Instructor - The flow of processed data to the "end-user" is a definite problem. Some data has an immediate use, with a very short useful life, others are so voluminous as to be two difficult to transport.

Instructional Objective - to make the student aware of the problems of getting timely data to the "end-user".

Instructional Method

1. Review the little game from the last activity, step #8. Interview the center student to see what problems he had, especially the probable problem of getting a "garbaged" sentence from the passers.

2. Present the problem of "closing the barn door after the horse has left". Example might be the CO problem of activity #1. If the readings were established by chemical analysis in the laboratory then sent to an air pollution control center, the data would be too late.

3. Have the students review their list for any data which should be processed and used immediately.

4. Present the problem of "swamping". The processing of large amounts of data for an average. Example - 32 pollution monitoring stations, with 16 possible pollution measurements, with a reading every minute. Have the students calculate the total number of readings in an hour. Have them add up a list of 60 figures, and take timings. Establish an average time and have them calculate how long it would take to produce each average, for each measurement, for each station.

5. Have the students select a fact from their lists and calculate how long it would take to produce an average.

6. Review the difficulties associated with timely processing of data.

Measurement of Instructional Objective - Given a number of different data recording devices, recording data at such and such rates, and working with average time of averaging calculations, calculate the time it would take to produce a series of averages.

ACTIVITY #9 - INFORMATION USE

Notes to the Instructor - Data when used is information, but how it is put to use, that is good or bad, is not the question.

Instructional Objective - to make the student aware that data being used is information, but that information used for "good" or "bad" is not a criterion.

Instructional Method

1. Announce that data gathered and processed is arriving at a useful time for the "end-user". Explore ways that data could be used. Example: CO measurement could be used by health authorities, manufacturing industries, etc.

2. Let the student select various ways his data could be used.

3. Present the concept of misuse of data. Such as the possible mercury level readings in fish being used to shut down the fishing industry.

4. Let the student select various ways his data could be misused.

5. Assign the students to review current articles which discuss some action proposed based on data. In the review, point out problems of gathering data, of timely distribution, and possible misuse.

Other Notes - This last part of this activity could create a long discussion on misuse. It is not the purpose at this time to discuss this only to make them aware. Avoid any lengthy conversations.

ACTIVITY #10 - TECHNOLOGY FOR INFORMATION

Notes to the Instructor - The previous section of the module discussed data gathering and processing, without the aid of any technology. The student has by now recognized the need for this equipment. This activity is to introduce the student to this equipment.

Instructional Objective - the student will become aware of the technology for information systems.

Instructional Method

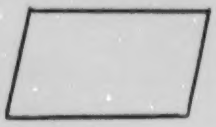
1. Present the concept of automated source gathering equipment, the computer, and communication systems. Rely on the examples of the past - using "wouldn't it be nice to have" approach. The actual equipment will be discussed in some detail in later objectives.
2. Build a block diagram of a simple information system (see handout).
3. Have the student diagram a similar system for one of his facts.
4. The student should probably come up with a similar diagram. Comment on the common system serving multiple users.
5. Discuss - Source Data Automation - the ability to gather data without the manual intervention.
6. Have the student select facts from his list which he believes could be source automated.
7. Discuss tele-communications - the ability to use existing telegraph and telephone lines to transmit data.
8. Have the student select that data which he believes could, and should, be sent via communication.
9. Discuss computing systems - the ability to store and process data at very high density and speeds.
10. Have the student select that data which could and should be processed by computing systems.

Measurement of Instructional Objective - The student will be given a fact and its use. Describe an information system which would use technology.

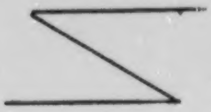
Other Notes - This section introduces the technology in an overview fashion. It is not designed to go into detail.

HANDOUT - INFORMATION SYSTEMS

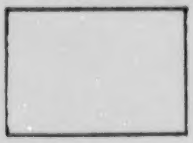
Gathering Data - a symbol



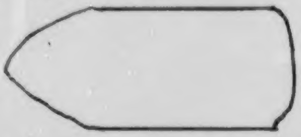
Sending Data - a symbol



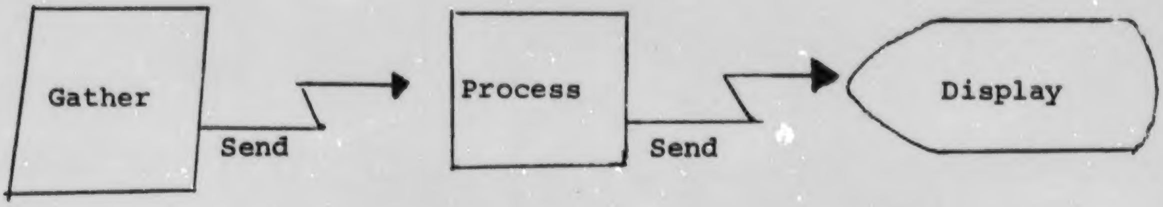
Processing Data - a symbol



Displaying Information - a symbol



An Information System in Symbols


Gather
Send
Process
Send
Display

ACTIVITY #11 - DATA GATHERING TECHNOLOGY

Notes to the Instructor - Data gathering devices today have been largely developed as need and cost have been justified. Most data in business and government has been manually gathered and recorded on forms, then key punched. This is also true with scientific data. In the very recent years the need for more data and for a more timely entry into an information system has created a large amount of R & D which has caused some very interesting technological developments. Termed, Source Data Automation, AC to DC equipment uses sensors for scientific data, and on-line transaction recording devices for government and business. This objective is to explore conceptually how these devices work.

Instructional Objective - to have the student conceptually understand how Source Data Automation equipment works and their basic function.

Instructional Method

1. Lecture on the principle of the flushing of a toilet. The water level is recorded and action is taken without manual interference.
2. Present the concept of sensors and their function. Example might be water sensors. Enclosed is a brief description of one sensor.
3. Present the concept of data gathering with a cash register using credit cards.
4. Have the students visit a large department store for examination of this equipment. Or arrange for NCR salesman to discuss the equipment.
5. Arrange a field trip to visit a municipal sewage treatment center, or have a local representative of an environmental agency or business discuss this equipment.

Measurement of Instructional Objective - The student will review an article in the library where source data automation is discussed.

Other Notes - This activity is *not* to make the student technically able to describe Source Data Automation. The idea of being able to mechanically gather data is one of the most important points for Information Systems. This activity most certainly could be expanded with various other exhibits and demonstrations.

ACTIVITY #12 - DATA STORING DEVICES

Note to the Instructor - In activity #6 the student discussed the advantages and disadvantages of sequential recording (on a roll of paper) and direct access recording (on 3x5 cards). This activity discusses the same concept using magnetic tape and magnetic disc.

Instructional Objective - to make the student aware of tape and disc recording devices.

Instructional Method

1. Review recording methods as discussed in activity #6.
2. Introduce the magnetic tape. Examine the difference between tape recordings and tape - that is the continuous recording versus bit recording.
3. Explain how these bits of data can be saved in a very small area - 1 inch of tape will hold 1600 coded digits. Examine how many numbers could be stored on the usual role of 2400 feet.
4. Discuss how the data might be retrieved, that is sequentially.
5. Introduce the magnetic disc as with a phonograph record. Examine the difference as before in step #10.
6. The additional difference of circular tracks versus a spiral track should be explained.
7. Discuss the ability of the read/write head (phonograph needle) to be picked up and set anywhere giving direct access.

Measurement of Instructional Objective - The student will explain the difference between tape and disc recording.

Other Notes - This section can be developed more thoroughly if time permits as to the types of data records, the concepts of read/write, the track/cylinder. Any standard introductory data processing textbook will provide the instructor with the technical concepts.

ACTIVITY #13 - COMPUTING TECHNOLOGY

Notes to the Instructor - In the last activity, mass storage was discussed. This section discusses the computer from its high speed point of view. It is not a detailed section, however, if time permits it could be expanded.

Instructional Objective - to make the student aware of the high speeds of computers, their place in the information system.

Instructional Method

1. Present the block diagram of a computer and discuss the Central Processing Unit (CPU). The Storage as the place where data is temporarily held until it has been stored or processed. The Control as the place where the computer program causes the computer to add, etc. The Arithmetic/logic unit as the place where the data is manipulated.
2. Discuss the speed of a computer. That is one execution on one piece of data in 1 millionth of a second. Have the student calculate the amount of executions that can take place in one second.
3. Refer to Objective #8, step 4. How many sensors could be averaged over one hour by one computer if it takes 4 millionths of a second to add, etc.
4. Visit your local campus computing center. Prearrange to have an averaging program demonstrated, the center should be able to write a small program and use any existing data card to show the entire operation. The time will take longer than calculated because of the input and output not having been calculated in step #3.
5. Review this visit and ask how much time went into Input/Output operation. (Most of the time) Ask what was happening in the computer while I/O was taking place (nothing). Explain the idea of several I/O devices and several programs using the computer by scheduling the programs to work when others are in the I/O stage. This concept of multi-programming is very important in information systems.

Measurement of Instructional Objective - The student will calculate how long an averaging of 800,000 numbers will take on a computer versus his manually calculating the average.

Other Notes - This activity is not lengthy because it is not the purpose of the module. The idea is to imply the rapid processing od data by a computer.

ACTIVITY #14 - COMMUNICATIONS TECHNOLOGY

Notes to the Instructor - The objective is to have the student look at his telephone in another perspective. The study of tele-communications like the past objective could be expanded. Again, this is a simple overview.

Instructional Objective - to make the student aware of the communication ability of his telephone and to lin together the computer and mass storage to a remote data gathering device, or to an "end-user".

Instructional Method

1. Review the basic telephone system. The phone, the circuit selector, the phone. Draw a diagram such as in Activity #11 without the computer.
2. Discuss line transmission speeds of a voice grade line - number/second.
3. Discuss the concept of a dial-up tele-communication system. That is the computer dials number of terminal, places call to sensor. "end-user" calls up computer, and computer gets data from mass storage - disc.
4. Discuss the concept of the information system as presented in Activity #11.
5. Have the student select one fact from his list, and superimpose an information system to provide information to the "end-user".

Measurement of Instructional Objective - The student will draw a diagram linking a computer to several sensors by tele-communication and to one "end-user".

Other Notes - This activity ends the conceptual background of the information technology, from what is a fact to communications. More time can be spent on each piece of equipment. Remember this module is developing a technological conception to assist in evaluating the growth of information technology.

ACTIVITY #15 - DATA TECHNOLOGY, THE INDIVIDUAL AND SOCIETY

Notes to the Instructor - This activity is intended to make the student aware of the effects of this technology.

Instructional Objective - To make the student aware of the changes to the standard of living of the individual and society that data technology has caused.

Instructional Method

1. Lead a discussion of some types of work, considered to be repetitive and uninteresting, that data technology has relieved the human from. An example of this is the posting of cashed checks. If this is done manually, in a highly organized system, this task would take three minutes. Using a not too unreasonable figure of 1,000,000 checks per day, how many individuals would be required assuming an eight hour day. (8x60/3 divided into 1,000,000 would be 6250). This task has been assumed by data technology.
2. Lead another discussion on multiphasic health testing centers - see TMMW. The use of data technology underlies this concept.
3. Have the students take a 'vacation' by planning the route and confirming reservations.
4. Reversing the trend, lead counter discussions. The lack of jobs, the potential of using the gathered data both health and reservation in a blackmail manner.
5. Lead a discussion on the right of privacy and the invasion of privacy. An example is the idea that the record keeping serves as a potential source to be used against one. This threat alone can suppress individual action, causing conformity.

ACTIVITY #16 - DATA TECHNOLOGY COSTS

Notes to the Instructor - There are two different costs to be considered. The actual dollar outlay and the costs in non-monetary value.

Instructional Objective - To make the student aware of how costs are used in determining the acquisition of systems of data technology.

Instructional Method

1. The first cost is feasibility. Is a proposed system feasible without the speed and storage capacity of data technology? Many systems present and proposed are only feasible if data technology is used. The responsible measuring of pollutants for instance.
2. Benefit - Most systems stress feasibility and costs with little regard to benefits. This area has been used by the professionals to support acquisition, but more recently, negative benefits have been used to defeat acquisitions.
3. Effectiveness - This term is used in relationship to other alternative systems (those without data technology).
4. Privacy - This is the key to the module. This cost is only recently being considered.

ACTIVITY #17 - CASE STUDY

Notes to the Instructor - The following hypothetical situation could most certainly happen. The student should be asked to read the case and consider it from the various concepts introduced in previous activities.

Instructional Objective - to summarize the module.

Case - A centralized bank of vital data on organized crime leaders as designated by the U.S. Attorney General.

The activities of organized crime leaders are closely monitored by several government agencies. The activites are observed and some recorded. Each agency maintains records considered of interest to that agency. Another agency may not even be aware of another agency's records, and may maintain duplicate data. In addition, observations made and not recorded because the fact is not considered vital to that particular agency may very well be vital to another agency.

The agency may have need to know the past activities of a crime leader. Obtaining this data requires extensive searching of voluminous files. The time required to obtain the data and use it as information may be so long that once the data is collected and organized, the information is lost.

Faced with the two situations described above, a proposed system of data technology has been designed to meet the various government agencies' needs. A computer will be installed with the whole purpose of maintaining a file on each designated organized crime leader. Connected to the computer will be thousands of typewriter devices (scattered throughout the world) accessible by every agency. These terminals will be used to enter every observation made and to print out the status of any or every record maintained. The file will be kept on magnetic disk which provides almost immediate access to any piece of data. The file will contain every piece of data that any agency would need. This joint pooling of the data will prevent duplicate data from being maintained and insure that all observations are recorded regardless of any particular agency's need. The file will be organized to allow any agency to obtain any data they need for information. In addition, with the speed of computers, every new activity can be compared with other records to determine if some cooperative action by the crime leaders is pending and notice can be issued.

Presently, without this system, several activities by organized crime leaders have gone unnoticed. One special activity has been unnoticed, the intrusion of crime leaders into legitimate business. These lawful activities are so numerous and seemingly unconsequential they have not been recorded. Yet these actions lead to the demise of the legitimate businesses, and should be stopped. The proposed system will make observation and recording feasible.

The benefits of this system are numerous. The individual will be better protected. If he is a customer of a legitimate business or the owner, he will be assured of protection from these crime leaders. Society will most certainly benefit. The taxes lost because of illegal business operations can be recovered.

The effectivness of this operation can easily be measured by the increasing percentages of arrest and convictions. The overall effectiveness will be the reduction of the number of crime leaders.

The case for privacy is moot. Persons operating in the area of crime have no rights, as they are not members of a lawful society.

POWER GENERATION

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TEACHING MODULE

POWER GENERATION

The following is a teaching module for a unit on power generation.

It is intended for students who do not intend to major in science or technology. The background of the students should include at least one course in elementary algebra.

It is suggested that the instructor have a background which includes at least four semesters of college level physics.

A period of three to five weeks is suggested, depending upon the depth in which the subject is treated. Supplementary work is to be presented during the laboratory periods.

The class meetings should consist of three lecture periods per week with a two to three hour weekly laboratory. One laboratory period should be set aside for an organized visit to a local power generating station.

POINTS OF DISCUSSION

Power Generation

I. Why the Current Controversy?

- a) Environmental effects.
  - 1) Pollution.
  - 2) Destructive alteration of natural topography.
- b) Direct physical effects on man.
  - 1) Radiation hazards.
- c) Threat of scarcity of present and future power requirements.
  - 1) Fossil fuel reserves.
  - 2) Current and potential nuclear fuels.
  - 3) Restrictions on construction of additional power generating plants.

II. Methods of Production - Advantages and Disadvantages.

- a) Fossil Fuels.
  - 1) Coal - direct burning - gasification.
  - 2) Oil.
  - 3) Natural gas.
- b) Hydro-electric.
  - 1) Natural - utilization of waterfalls.
  - 2) Artificial.
    - i) construction of dams.
    - ii) pumped storage during low usage times.
- c) Nuclear Power.
  - 1) Fission reactors.
  - 2) Breeder reactor.
  - 3) Fusion reaction.
- d) Alternate methods.
  - 1) Solar energy.
  - 2) Tidal energy.
  - 3) Geothermal energy.

III. Goals and Objectives.

More reasonably informed society for the purpose of making decisions based upon:

a) the need for electrical energy.
b) an awareness limitations and capabilities of present technology.
c) a recognition of need for continuing research to:
    1) improve efficiency of existing methods of production.
    2) develop new and better methods of production.

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I. INTRODUCTION

The present awareness of energy use and the resulting effects on the environment has maintained a controversy as to what the future holds in store for us. Recent failures in production and/or distribution of electrical energy, from the great Northeastern Black-out of 1965 to the local selected black-outs and brownouts of 1971 and 1972, have focussed much of the controversy onto the production and use of electrical energy.

The severity of the problem may be highlighted by an extremely curious event which is now taking place (Spring 1972). Consolidated Edison, a corporation whose prime reason for existence is that of selling a product (electricity) for a profit, is waging an advertising campaign to discourage the use of its product. Although the copy writers are aiming their "save a watt" messages at an environmentally and conservation minded audience, a high level of sophistication is not needed to realize that the reason(s) behind this apparently noble act by Consolidated Edison are not as altruistic as they would want everyone to believe. Simply put, our technological society has (in effect) developed the means of consuming more electrical energy than it can produce in certain parts of the United States. That is, in heavily populated, highly industrialized centers, the demand exceeds the supply at peak usage periods. Therefore, we must produce more or use less, or more serious difficulties will arise.

Since both power production and population are allowed to grow (and in some quarters, encouraged to do so), the existing problems are compounding. The United States population is expected to more than double by the year 2000; growing from 152 million (1950) to 320 million. However, since this population (because of advancing technology and affluence) is expected to greatly increase its consumption of electricity (energy), its impact on the environment (from pollution, physical and aesthetic, to fuel sources and reserves) will more than double. Each of those 320 million Americans will represent an electric power consumption of twelve and one-half of their 1950 predecessors.* Or to put it in another way, the effect on the environment from the power production for our population in 2000 will be equal to the effect of 4 billion 1950 Americans.[1]

The problems of production of electrical power are many and varied, but those of major concern seem to be:

1) the environmental effects
2) the availability, present and future, of fuels used in its production

To investigate these problems in any depth at all, requires a look at the various methods of production. The major sources of electrical energy[2] and the projected growth rate[3] are:

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*Based on the growth rate for the demand for electric power to double every 10-15 year period. Doubling times of 10 years and 15 years appear often in related literature.

Source of Electrical Energy 1971	Projected Growth Rate %/yr. 1968-2000
oil -- 8%	3%
natural gas -- 20%	2%
coal -- 55%	3%
hydro-electric power -- 15%	
nuclear -- 2%	17½%

From the above data, it can be seen that the preponderance (more than 85%) of electrical energy producted in 1971 is the result of the conversion of fossil fuels.

II. METHODS OF ELECTRICAL ENERGY PRODUCTION

A. Hydro-Electric (Water→Electricity)

Water in motion possess the energy (kinetic energy, or energy of motion) to turn a wheel (turbine). This in turn is connected to a generator which converts the mechanical energy into electrical energy.

Hydro-electric power is utilized in several forms. Water wheels or turbines can be directly driven by rapidly moving rivers or natural waterfalls. Water can also be pumped into high storage tanks during periods when demand for electrical power is light. Fuel is consumed in this process, to produce the electricity to drive the pumps. At periods of large demand of electrical energy, the water is allowed to fall, thereby turning turbines, converting the stored (potential) energy of the water to electrical energy.

Utilization of naturally moving water creates negligible environmental problems. However, when hydro-electric power is achieved through the damming of rivers, thereby creating artificial lakes, changes in the local ecology can occur which may have disastrous consequences. The Aswan High Dam on the Nile River in Egypt is a case in point.

The Aswan High Dam was conceived and built with a variety of purposes in mind, one of which was "clean" hydro-electric power. The political, economic, and environmental consequences of its construction are continually unfolding, and history may show that its final impact may be more of a disaster for Egypt and the Eastern Mediterranean area than the major national asset it was conceived to be.

The High Dam, designed by West German engineers, approved by the World Bank, initially to be financed by the United States (which withdrew its backing for political reasons) was finally underwritten and built by the Russians.

The political dispute surrounding the Dam precipitated President Nasser's break with the West, nationalization of the Suez Canal (which triggered the Suez War), and opened the door for direct Soviet involvement in Egypt, the Middle East and the Mediterranean.

The prime purpose of the Dam was to control and store the Nile's waters for irrigation of existing land, reclaim land from the desert and guarantee against drought and famine. Hydro-electric power, enough to supply half of Egypt's power requirement, was to be an additional, peripheral asset.[4] The ecological disruption caused by its construction is independent of the reasons for which it was built.

A prominent Egyptian hydrologist, Dr. Abdel Aziz Ahmed, warned of the potentially disastrous consequences should the Dam be built and was fired for his trouble. That of which he warned, has, to a greater or lesser degree, come to pass, namely:

1) The dam would trap the fertile silt which nourished the shores of the Nile in its downstream journey.
2) The silt-free water would cause severe erosion problems downstream.
3) The loss of water from the lake formed behind the dam, due to evaporation, seepage, and changes in underground water movements would ultimately leave Egypt with less water after the dam than before.[5]

Egyptian farmers are now forced to artificially fertilize lands which were once among the most fertile on earth. Increased salinity in the Delta and Middle and Upper Egypt areas due to the decrease in fresh water flow is endangering millions of acres of farmland, and will continue to do so as long as the Dam exists until elaborate drainage systems are constructed.

Approximately 700,000 acres have been converted from flood to canal irrigation enabling a substantially increased yield. Here too, however, negative side effects of immense proportions have arisen.

Bilharzia (schistomiasis), a disease known to ancient Egypt, has reached plague proportions with the advent of extensive irrigation. The principle carrier, a snail, cannot survive in fast flowing water, but once established in placid waters (such as those of the shoreline of Lake Nasser formed behind the High Dam), the snails can multiply at a rate which will increase their number by 50,000 fold in four months. Although the snail does not attack human beings, it is the host for the parasites which do.

Even though the disease is more debilitating than fatal, one out of every ten deaths in pre-High Dam Egypt was caused by it, and the cost to the state in lost working time alone ran to half a billion dollars yearly. There seems to be no official figures which cite the number of additional victims since the High Dam was completed.

There is no lasting cure for bilharzia, since anyone can become reinfested with the parasite merely by coming into contact with contaminated water.

Another potential health hazard of the High Dam is due to the creation of vast breeding grounds for the Anopheles gambia mosquito, the deadliest malaria carrier in Africa. Some strains of this mosquito have already developed immunity to DDT. Therefore, extreme diligence will be required to prevent its getting a foothold in a seemingly made to order environment.

Since storage of water was the prime reason for the construction of the High Dam, its shortcomings in this may perhaps be the most ironic. Losses due to evaporation, seepage through porous sandstone, and the rerouting of underground movements due to external pressure have resulted in a lower net supply to Egypt.

And finally, once abundant quantities of sardines, mackerel, lobster and shrimp have been all but decimated along Egypt's Mediterranean Coast. A major contributing cause is the reduction by about two-thirds of the nutrient plankton and organic compounds in the coastal waters. The uninterrupted Nile was the source of these nutrients.[6]

The building of the High Dam required a vast capital outlay--an investment which theoretically should earn interest. Each of the resulting problems discussed above (and these are by no means all of them) has a cost factor associated with its control or reversal. To date the liabilities outweigh the assets!

B. Fossil Fuel Plants

Where electrical energy is produced by the burning of fossil fuels, peripheral problems become seemingly insurmountable. The general process, regardless of the type of fuel used is as follows:

1) fuel is burned in a furnace producing steam in a boiler
2) the steam is directed under pressure to turn a turbine
3) the turbine is connected to a generator which produces electrical energy.

In the first step of the process, the burning of the fuel adds contaminants or pollutants to the atmosphere in the form of a) gases, b) particulates, and c) thermal energy (heat) vented through the smoke stack. In addition, solid waste products (if coal is used as fuel) are produced as a result of incomplete combustion.

In step two, after the steam has been used to drive the turbine, cooling takes place. In a condenser, through which water is piped from a nearby lake, pond, river, etc. the steam is converted back to water for recycling back to boiler to produce high pressure steam once again. The water which has been used in the condenser as the coolant is returned to the body of water from which it came.at a higher temperature than at intake. This results in a "thermal pollution" which can have negative results in regard to the immediate ecology.

Finally, in step three, the desired result takes place--electrical energy is produced. The electricity thus produced must be distributed for use. For this purpose transmission cables, usually over ground, are constructed. Outside of use of land, vulnerability to extremes of weather and being an occasional obstacles to vehicular traffic, primarily automobile, the method of transmission of electrical power is not usually considered to be as significant a problem as its production.

As a typical example in a fossil fuel plant operation, a coal fired plant is offered. For 683 pounds of coal used in a power plant, and which contains 2.5% (17 lbs.) sulfur and 10% (68 lbs) ash, the following takes place:[7]

1) 8,540,000 Btu of heat are produced.[*]

2) 1,280,000 Btu of heat are rejected through stack and to the turbine and the generator.

3) 3,845,000 Btu of heat are rejected into cooling water circulated through condenser.

4) 3,415,000 Btu of useful heat, that is, heat energy that has been converted into the originally desired product--electricity.

5) Air is contaminated with

    a) 34.2 lbs. sulfur oxides
    b) 6.83 lbs. nitrous oxides
    c) 1.37 lbs particulates
    d) hydrocarbons, carbon monoxide, carbon dioxide

---

[*] A Btu (British thermal unit) is a unit to measure energy content of heat. The definition, the Btu is the amount of heat energy necessary to raise the temperature of 1 pound of water 1 degree Fahreinheit, may not be as important for these purposes as a relative understanding of its size. For example, in completely burning 1 gallon of gasoline, 120,000 (12×10^4) Btu of heat are produced; in leaving a 100 watt light bulb on for 1 hour, about 360 (3.6×10^2) Btu of heat are produced.

6) Solid waste (ashes, clinkers, etc.)

7) Contamination of cooling water due to addition of chemicals to control slime and corrosive action on condenser tubes.

The description above of a coal fueled power generating plant does not deal at all with the acquisition of the coal or any other fossil fuel. Much has been said and written recently about the availability of fossil fuels and their reserves. Estimates of reserves range from 12 years for natural gas to 2000 years for known coal deposits.

A popular estimate of the growth rate of the demand for electrical power, as stated earlier, is that the demand is doubling every 10 years. Let us assume this rate to be correct, and let us assume further that .1% of the earth's total fossil fuel reserves have already been extracted. The following table shows how rapidly a doubling rate of use of the fuels would deplete the existing reserves.

Doubling Period	Amount Depleted Per Period	Total Depletion
Now	.1%	.1%
1	2 x .1% = .2%	.3%
2	2 x .2% = .4%	.7%
3	2 x .4% = .8%	1.5%
4	2 x .8% = 1.6%	3.1%
5	2 x 1.6% = 3.2%	6.3%

6	2 x 3.2% = 6.4%	12.7%
7	2 x 6.4% = 12.8%	25.5%
8	2 x 12.8% = 25.6%	51.1%
9	2 x 25.6% = 51.2%	102.3%

In less than 9 doubling periods or less than 90 years, the supply would be exhausted, using the assumed values. If, in fact, the already consumed reserves were only a millionth of a per cent (.000001%) of the total rather than the .1% value assumed above, total depletion would occur after twenty-six doubling periods, or in about 260 years.[8]

This illustrates that an unchecked growth rate can make short work out of what may initially seem to be an inexhaustable supply.

The production of electrical power does not begin at the site of the generating plant. Mining of coal, drilling for oil, transportation, processing, and storage are also important factors that must be considered.

i. Mining and Transportation of Fossil Fuels

The strip mining of coal produces some of the worst environmental effects. When water runs over this type of shallow exposed mine, sulphuric acid is washed into streams and rivers upsetting the underwater ecology making fish from these waters impalatable. Widespread strip mining has produced serious landslides and erosion problems. Once beautiful mountains have been left as deforested areas covered with deep trenches and cast-away rock and coal. Other forms of coal mining are inherently dangerous to the miners themselves, causing respiratory diseases, including the "black lung" disease, which affect large numbers of miners.[9]

After the mining, vast networks of transportation and storage facilities are required for this bulky fuel. The weight of the fuel itself requires substantial energy consumption for its transportation. This drawback has been partially alleviated by on site construction of power plants. That is, in certain instances generating stations have been built right at the source of the fuel, the coal mine. This, however, can be only a temporary advantage, since the amount of coal is finite. Once is has been economically mined, either the generating station must be moved, or the fuel must again be transported to it.

The drilling of oil has its own peculiar environmental and ecological effects. These are not considered as significant as those problems encountered in transportation and storage, especially the former.

The primary means of transporting oil are by ocean going tanker and pipeline. Each has had its share of publicity or notoriety in recent years.

"During 1969, two hundred thirty four ships carrying cargoes of oil crashed into one another, dashed themselves upon reefs, or otherwise did themselves in."[10] This statement clearly poses the environmental and ecological dangers that necessarily exist in the process of fuel transportation. Since "ten foreign nations produce 57% and export 85% of world oil" and "Europe and Japan import 95% of their oil needs",[11] it is obvious that the threat of accidential oil spillage will become greater as the demand for the fuel increases to meet the needs of the increasing demand for oil. A vast building program for oil tankers is currently underway. The Japanese are building 1280 foot tankers (almost as long as the Empire State Building is high) of 500,000 deadweight tons. These ships are capable of carrying about five times as much oil as the Torrey Canyon, the ship which broke up on a reef in the English Channel in 1967, causing a major disaster. The English have on the drawing boards a tanker of 1,000,000 deadweight tons, or nearly ten times as large as the Torrey Canyon. "And, in case you think something about their being bigger makes them safer, consider this: If the Captain of one of those 250,000 tonners* from Alaska sees trouble ahead while going full speed, it will take him a half hour to stop the thing![12]

Since the recently discovered oil reserves in Alaska are located on its Northern shore, Prudhoe Bay, the transportation by tanker is difficult because ice makes these waters less than navigable during much of the year. To meet this problem, a pipeline, 790 miles long, has been proposed from Prudhoe Bay to Valdez, a seaport on Alaska's southwestern shore. This pipeline which will climb mountains, cross numerous streams and active earthquake faults, presents many severe potential hazards:

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*250,000 ton tankers are now being used to carry oil from Alaska to the West Coast of the United States.

1) the oil must be heated in order that it may be pumped along its route. This heating (150-160°F) could cause melting of the perma-frost (permanently frozen ground beneath the Alaskan tundra) which in turn could cause ground shifts which could result in pipe failure.

2) the pipeline has twelve shut off stations along its route. Each mile of pipe will contain 11,000 barrels of oil, therefore, a break could potentially spill the oil in 60 pipeline miles at 11,000 barrels per mile, or 660,000 bbls of hot oils on the delicate tundra. This would be equivalent to 2 of the Santa Barbara spills, where an off shore well ran wild loosing oil into the ocean. A spill in colder climates could be potentially more disastrous, since the oil would not readily degrade due to the cool temperatures.

3) the storage area in Valdez is located in an areas which which was totally destroyed in the 1964 Alaska earthquake. The old-wives tale that "lightning doesn't strike twice in the same place" doesn't apply to earthquakes.

4) the route traveled by tankers from Valdez to the Western Coast of the United States is also especially hazardous.

Because of the prevailing currents, a spill along this route could effect the entire West Coast.[13]

It should be pointed out that there are positive energy considerations with respect to the pipeline. Should none of the above disasters materialize, the delivery of the Prudhoe Bay oil to the southern coast of Alaska will have the following advantages:

1) less energy will be consumed in its transportation.
2) the delivery of oil will not be limited to summer months.
3) adverse weather conditions will have little or no effect on oil supply.
4) the danger of collision of oil carrying ships will be decreased (in those areas which will no longer have tanker traffic).

It should be obvious that as demand for electrical energy rises even more rapidly than the increase in population, that the inherent dangers in its use will also rise. To meet these dangers, stop gap measures are being taken as technology permits.

1) Since coal is our primary present source of energy for electricity, efforts are being made to increase its efficiency from 40% to 50-55%. One method of increasing the use of coal, the most abundant fossil fuel, while simultaneously reducing its polluting effects is through a process called coal gasification. Natural gas, while being the "cleanest" fossil fuel is also the least available.

The technology for gasifying coal exists, but at the present time the cost factor is not economically attractive for large scale production. In his June 4, 1971 message to Congress on national energy requirements, President Nixon pledged his support to "An expanded program to convert coal into a clean gaseous fuel."[14]

Besides reducing the detrimental characteristics associated with burning coal as fuel, gasified coal will greatly reduce the transportation problems since gas can be easily moved via pipeline.

Though these measures will prolong the reserves, and decrease pollution factors, there is no answer to the destructive nature of mining itself.

2) To increase efficiency of steam electric plants, a magnetohydrodynamic (MHD) tapping cycle is in the research and development stage. In this process the hot gases are passed through an MHD generator before entering the boiler to generate steam. "The generation of electric power through magnetohydrodynamics is based on the motion of a conducting fluid (usually a high velocity gas) through a very strong magnetic field..."[15] By this technique, electricity is "tapped off" the hot ionized gases before these gases produce the steam which ultimately drives the generators.[16]

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3) Recycling waste thermal energy now pumped into bodies of water or the atmosphere. This energy having been removed in the condensation process in steam electric generation. The coolant used to condense the "spent steam" which has been used to drive the turbines to produce electricity, is usually pumped into the system from a nearby body of water at a low temperature, and returned at a higher temperature. Besides "wasting" the heat energy, this can and does produce negative ecological changes. Con Edison, of New York utilizes this "waste" energy by selling "heat" to their customers--a type of large central heating system. Use of this nature could be expanded--especially if power stations were built on a smaller scale and were more centrally situated with respect to potential consumers.

These are just several of various attempts to improve the efficiency of fossil fuel plants. Although there will be positive short term effects, what is needed are alternative methods of generation of electrical power.

Although at present time only 2% of our electricity is generated by using nuclear fuel, "...it may well supply more than 50% by 1990. The Atomic Energy Commission has already approved plans for 51 plants, now being built, and 61 more that are ready for construction."[17] There are many reasons for the delay in construction of nuclear power plants; concern of citizens groups regarding thermal and radioactive pollution being among the more prominent.

C. Nuclear Power

To the average citizen, nuclear power brings to mind either the atomic bomb or the hydrogen bomb or both. To the more scientifically oriented person, nuclear power means either a fission reaction or a fusion reaction.

Both the fission and fusion reactions are based on the principle which is implicitly stated in the now famous "Einstein equation"

$$E = MC^2$$

where E is energy
M is mass
C is the velocity of light.

The principle simply stated is that there is a mass (matter)-energy equivalence. That is, should matter be "destroyed", an equivalent amount of energy is liberated, or should energy "disappear", an equivalence of mass (matter) somewhere appears. The equation above states this equivalence: by multiplying the amount of mass being converted into energy by the speed of light (186,000 miles per second) squared, we know how much energy is to be liberated.

Before fission and fusion are discussed as such, a description of a nuclear power plant, similar to that of a coal powered plant which was presented earlier, follows.* (Figure 1)

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* The present day nuclear power plants use fission reactors. The fusion reaction has not yet been harnessed in a controlled manner necessary for production of usable energy.

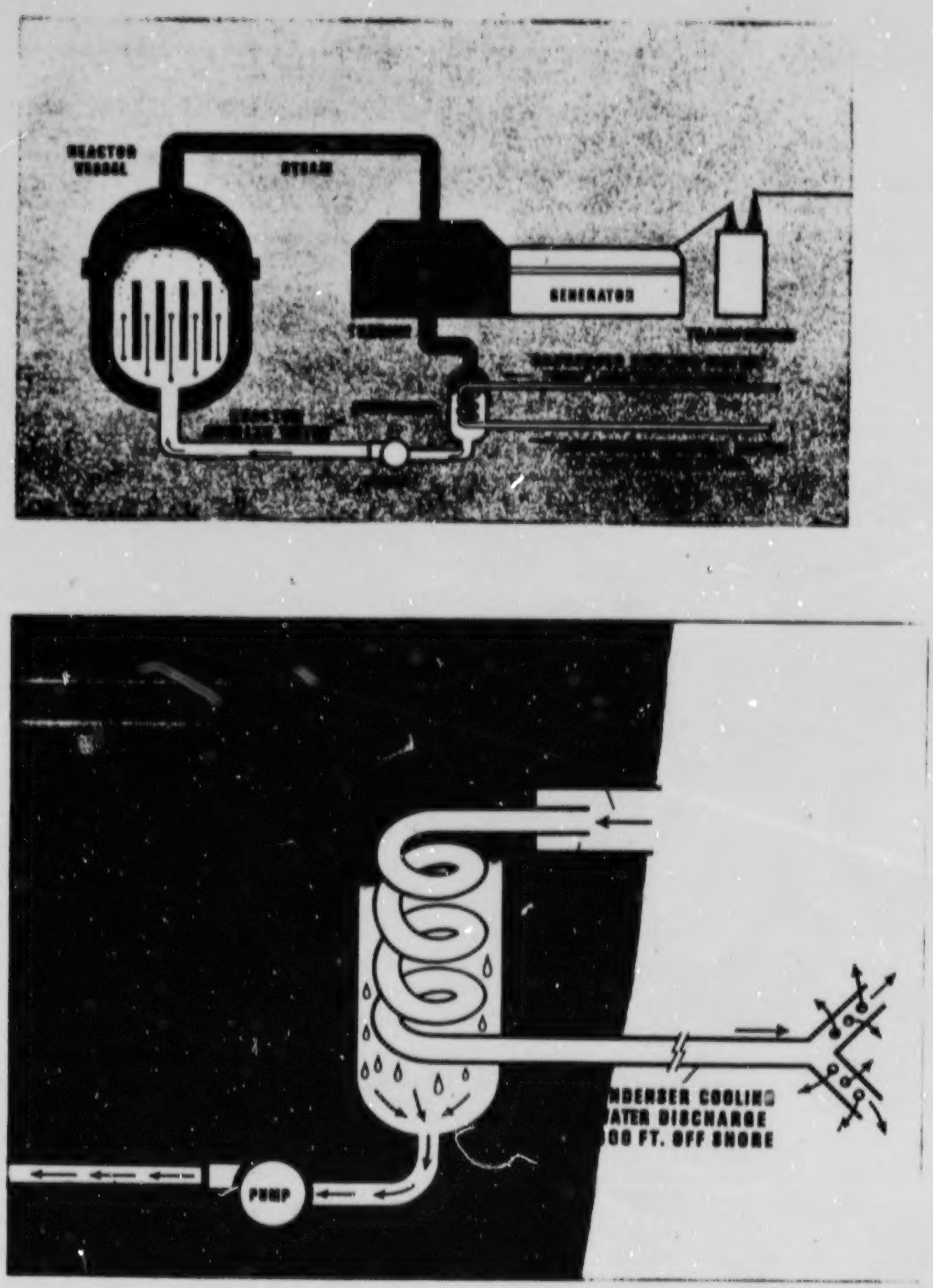
REACTOR VESSEL
STEAM
GENERATOR
TURBINE
TRANSFORMER
PUMP
NDENSER COOLING
ATER DISCHARGE
00 FT. OFF SHORE

FIGURE 1. SCHEMATIC DIAGRAM OF A NUCLEAR POWER GENERATING INSTALLATION

(Source: " The Shoreham Nuclear Power Station", Long Island Lighting Company, 1972)

In a typical nuclear power plant, the process is much the same as that described in page 7. Forty two ten thousandths of an ounce (.0042 ozs) of uranium undergoing fission in a reactor produces:[18]

1) 10,700,000 Btu of heat in the boiler.

2) 3,415,000 Btu of useful heat yielding 1 megawatt (1 million watts) of electrical power.

3) 7,285,000 Btu rejected into cooling water circulated through condenser.

4) Contamination of water by chemical additives used to control slime and reduce corrosion of condenser pipes.

5) Radioactive waste produced in fission process which must be stored, then transported to a "safe storage" location.

6) Potential contamination of water by liquid radioactive waste.

7) Increased radioactivity in vicinity of power plant.

Where the fossil fuel plant operated (as described) with an efficiency of 40%, the nuclear plant operates with an efficiency of 32%. However, one point is very clear--as inefficient as the nuclear plant is, a little over four thousandths of an ounce of nuclear fuel produced as much usable energy as almost one half ton of coal. This then suggests the question of availability of fuels that can be used in a fission reactor.

The world resources of the basic materials used in a fission reactor, namely uranium and thorium minerals, are fairly abundant. Although the potential for nuclear power is several orders of magnitude (powers of ten) greater than that which exits from all forms of fossil fuel combined, the fissionable material available in high grade ores is severely limited. The use of low grade ores to yield usuable fuel, thus far, would put nuclear power out of a cost-competitive race with fossil fuels.[19]

A solution to the fissionable fuel problem will be the development and refinement of what are called "breeder reactors." The breeder reactor is a fission reactor that will, in the process of converting nuclear fuel to electrical power, produce more fissionable fuel for future use than it uses.[20] However, the massive "burner" (what the fission reactors of today are called) program that has been undertaken is calculated to deplete the reserves of uranium 235 in such a short time that the breeder reactors may not yet be developed for use on a power production scale.[21]

In an effort to expedite the development of cleaner and more efficient power production, and to forestall a nuclear fuel crisis, President Nixon included Federal support for the development of the breeder reactor in his previously cited energy program. "Our best hope today for meeting the Nation's growing demand for economical clean energy lies with the fast breeder reactor. Because

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of its highly efficient use of nuclear fuel, the breeder reactor could extend the life of our natural uranium fuel supply from decades to centuries, with far less impact on the environment than the power plants which are operating today."[12]

However, the controversy surrounding the construction of nuclear plants has little or nothing to do with the economics of operation but with the hazards, both operative and those due to accidents.

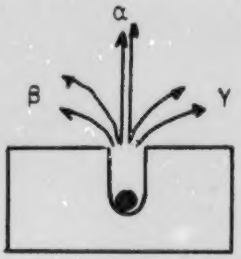
Although the nuclear plant has the distinct advantage of not producing any of the noxious and sometimes poisonous air pollutants for which fossil fuel plants are infamous, their distinct disadvantage lies in the inherent characteristic of radioactivity. These hazards exist in the mining of the fuel, its refinement and preparation, transportation, storage, use at the plant site itself, the waste and byproducts, transportation of the waste and byproducts and finally the disposal of the wastes.

Since radiation is a necessary part of nuclear fuel use, it is important to determine whether or not some limits to exposure can be established. "Basic to the consideration of health hazards from any toxic material and to the establishment of any meaningful standards for allowable exposure is the effect on health to be expected from any given exposure, and the question of whether there is a threshold--an exposure below which the material has no ill effect."[23] The Federal Radiation Council has adopted the posture that a threshold does not exist, and that "---every use of radiation involves the possibility of some biological risk either to the individual or his descendants."[24] Since it is fairly well agreed that "no radiation is good radiation", then if it is a necessary evil it must be minimized.

i. Radioactivity

In the late 1800's and early 1900's scientific research spearheaded by the scientists Roentgen, Becquerel, the Curies, and Villard opened the door to a new field of endeavor-nuclear physics. Their investigations showed that certain compounds emitted invisible radiations with varying capabilities of penetration. It was found by Mme. Curie that among the then known compounds, only those of uranium and thorium possessed this property, and she coined the terms radioactive and radioactivity to describe the process.[25]

Investigation showed the radiation to be of three distinct types. By passing the radiation through a magnetic field, it was seen that one "particle" was not deflected, while two others were deflected in opposite directions, as shown below:



(Magnetic field
perpendicular to paper.
North pole below paper)

It was found that the least penetrating radiations were bent to the right, the moderately penetrating, to the left, with the most penetrating passing through the field undeflected. Further, it was found that the first two were particulate while the latter was not, having similar characteristics to those of x-rays.[26] This led to the conclusion that the source of the radiation was the nucleus itself and that it was disintegrating.

The most massive (least penetrating) of the particles was named an alpha (α) particle; the second,a beta (β) particle; and the radiated wave (photon) was called a gamma (γ) ray. The alpha (α) particle turned out to be a helium ion (the helium atom with its electrons removed, therefore, just the nucleus itself) while the beta (β) particle was found to possess the characteristics of an electron (e^-) traveling at very high speeds (high energy). The gamma (γ) ray was resolved to be a high frequency, high energy, electromagnetic radiation. Since the source of the radiation is the nucleus, a transformation must take place upon emission of radiation.

The basic constituents of a nucleus are protons and neutrons, which have approximately equal masses with the proton having a unit positive electrostatic charge and the neutron being chargeless or neutral. The atom of an element is identified by the number of protons in its nucleus, and its mass is determined by the sum of the protons and neutrons.

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For example:

Hydrogen	${}_1H^1$
Carbon	${}_6C^{12}$
Oxygen	${}_8O^{16}$
Radium	${}_{88}Ra^{226}$
Uranium	${}_{92}U^{238}$
or in general	${}_ZX^A$

where "X" signifies the name of the element, "Z" the number of protons in the nucleus (called the atomic number), and "A", the sum of the numbers of protons and neutrons found in the nucleus, is called the mass number.

Therefore, the radioactive process, or the "radioactive decay" of a nucleus will result in the formation of a nucleus of another element altogether. When an alpha (α) particle is emitted, the atomic number of the newly formed nucleus is decreased by 2 since the α particle contains 2 protons, and the atomic mass is decreased by 4 because 2 neutrons are also contained in the α particle. This may be represented symbolically as:

$${}_ZX^A \longrightarrow {}_{Z-2}X^{A-4} + {}_2\alpha^4$$

The emission of a beta (β) particle poses a slightly different problem. It has been previously stated that the nucleus is primarily made up of protons and neutrons, with no mention being made of electrons. This problem can be resolved if one considers the neutron to be comprised of a proton (charge +1) and an electron (charge -1). This explains the neutral charge on the neutron and since the electronic mass is about $\frac{1}{1800}$ that of a proton, the combined masses are equivalent to the measured mass of a neutron.

One can think of a beta (β) emission as having originated in a neutron within the nucleus. The effect of this, then, would be the removal of a negative charge, which would result in a nuclear charge gain of +1. Or, a neutron, charge 0 has become upon β emission, a proton, charge +1. Again, in symbols:

$$_{Z}X^{A} \longrightarrow {}_{Z+1}X^{A} + {}_{-1}\beta^{0}$$

As for the gamma (γ) emission, since the γ is electromagnetic radiation, no change of mass occurs as a result of the emission of a γ ray. The nucleus can be thought of as having been in an excited energy state prior to emission and with emission, settling down to a more stable energy configuration.

It has now been determined that every element whose atomic number is greater than 83, or whose atomic mass is greater than 209 is radioactive.[27]

That radioactivity is hazardous to health is currently common knowledge. However, there is disagreement even among the most knowledgeable in the field as to what constitutes safe or permissable levels of radiation.

The units of measurement associated with radioactivity and radiation can also lead to confusion.

The most common units are: The curie, the rad, the roentgen, and the rem. Before attempting to define these units, it will be useful to understand another term which is commonly used when radioactivity is discussed, namely the half life or half period of a radioactive substance.

It was fairly quickly established that the rate of decay of any given radioactive element could not be affected externally. That is, the number of emissions per unit time could not be increased or decreased by changing the temperature or pressure of the material under consideration. In other words, the activity of a radioactive element is constant and is characteristic of that element itself. The term half life or half period was coined to describe the length of time required for half of a given amount of the material to undergo spontaneous emission. Actual rates of disintegration vary from less than 1% of the atoms decaying in a century to a high percentage of transmutations in a second.

The *curie* (c) is the unit of quantity of radioactive material. It is that quantity in which nuclei will disintegrate at the rate of 3.7×10^{10} per second.[28] From this definition it can be seen that the amount of material required for a *curie* is dependent upon the half life. Less material is required if the half life is short as compared to more for a longer half life.

The *rad* is the unit of dose of particle radiation and is described as the energy absorbed per mass of absorbing material.

Quantitatively, one rad is equal to 100 ergs (energy or work units in the centimeter-gram-second system of units) absorbed per gram of absorbing material.[29] The exposure unit for photon (gamma) radiation is the roentgen, which is related to the ionization (the removal of electrons from the atomic or molecular structure) of air.

The passage of one roentgen of radiation will result in the production of 2.083 x 10^9 ion pairs per cubic centimeter of dry air at standard temperature and pressure, or zero degrees centigrade, and 14.7 lbs per square inch. The energy absorbed in human tissue for one roentgen is approximately equal to one rad.[30]

Finally, the rem is an acronym, described, depending upon the author, as standing for either "roentgen equivalent man", or "rad equivalent man." Since, as was previously stated, the energy absorbed in tissue for both the rad and the roentgen is approximately equal, either description is permissible. The rem is defined as the quantity of any ionizing radiation which has the same relative biological effect as one rad of x-rays in the usual energy range. The radiation dose in rems is equal to the dose in rads times the relative biological effectiveness (RBE) of the radiation. Doses in rems are approximate since the relative biological effectiveness of one rad due to beta particles would not be the same as that due to alpha particles.

Maximum permissible doses (MPD) are based upon total accumulated exposure[31] rather than short term allotments, and are measured in rems.

The MPD accumulated, for those whose occupations are associated with radioactivity, to the whole body is, in rems, at any age, equal to five times the number of years beyond age 18, with no single annual dosage exceeding fifteen rems. No occupational exposure before age 18 is permitted.

For the general population, the MPD is significantly lower. The maximum permissible dose to the gonads from all sources, natural and man made is not to exceed an average of fourteen rems from conception to age 30, and one third of that for each decade thereafter.[32]

The unit most commonly used in the measure of radiation is the rem. The following table will serve to put the levels of radiation from a variety of sources into perspective:

Exposure to Ionizing Radiation

from Various Sources[33]

(Average annual exposure in millirems--there are 1000 millirems in a rem)

Natural background, cosmic rays radioisotopes in soil, etc.	100 to 150
Medical Use	
Exposure to gonads	50
Exposure to bone marrow	125
Fallout from weapons testing at present	10
To the general population from the nuclear industry	2 to 10
Maximum allowable under Present A.E.C. Standards (above natural background)	
General population	170
Individuals with General population	500
Individuals employed in nuclear industry	5,000

The principle hazards are genetic damage (damage to future generations), tumors and shortening of life span. Although the risk to an individual is low, the risk to the population is relatively high.[34] When minimum standards are set, industry usually uses these as an operating level. It seems that if radiation from nuclear power is inevitable, and that no threshold for radiation exists, standards should be set by technological limits, while still making possible the development and use of nuclear power.

ii. The Fission Reaction

The atomic nucleus is made up of a variety of particles, the major ones being the proton and the neutron. Each is very nearly equal in mass but while the proton has an electrical charge, referred to as plus one, or simply +, the neutron is electrically neutral, or has no charge. The nuclei of elements range from 1 proton for hydrogen, the lightest element, to 257 protons and neutrons in a manmade element called Lawrencium. Uranium 235 contains 92 protons and 143 neutrons.

When the nucleu of a Uranium 235 Atom is struck by a free neutron, the nucleus splits, forming two lighter nuclei and more free neutrons. These free neutrons can then collide with more Uranium 235 nuclei and continue the fission reaction. (See Fig. 2)

The fission products are important when the understanding of the energy released in this type of reaction is desired. Each proton and neutron has a definite mass. However, when the mass of any nucleus is determined, it is found that this mass is less than that which would be obtained if the masses of the constituent protons and neutrons were summed. This "mass defect" is related

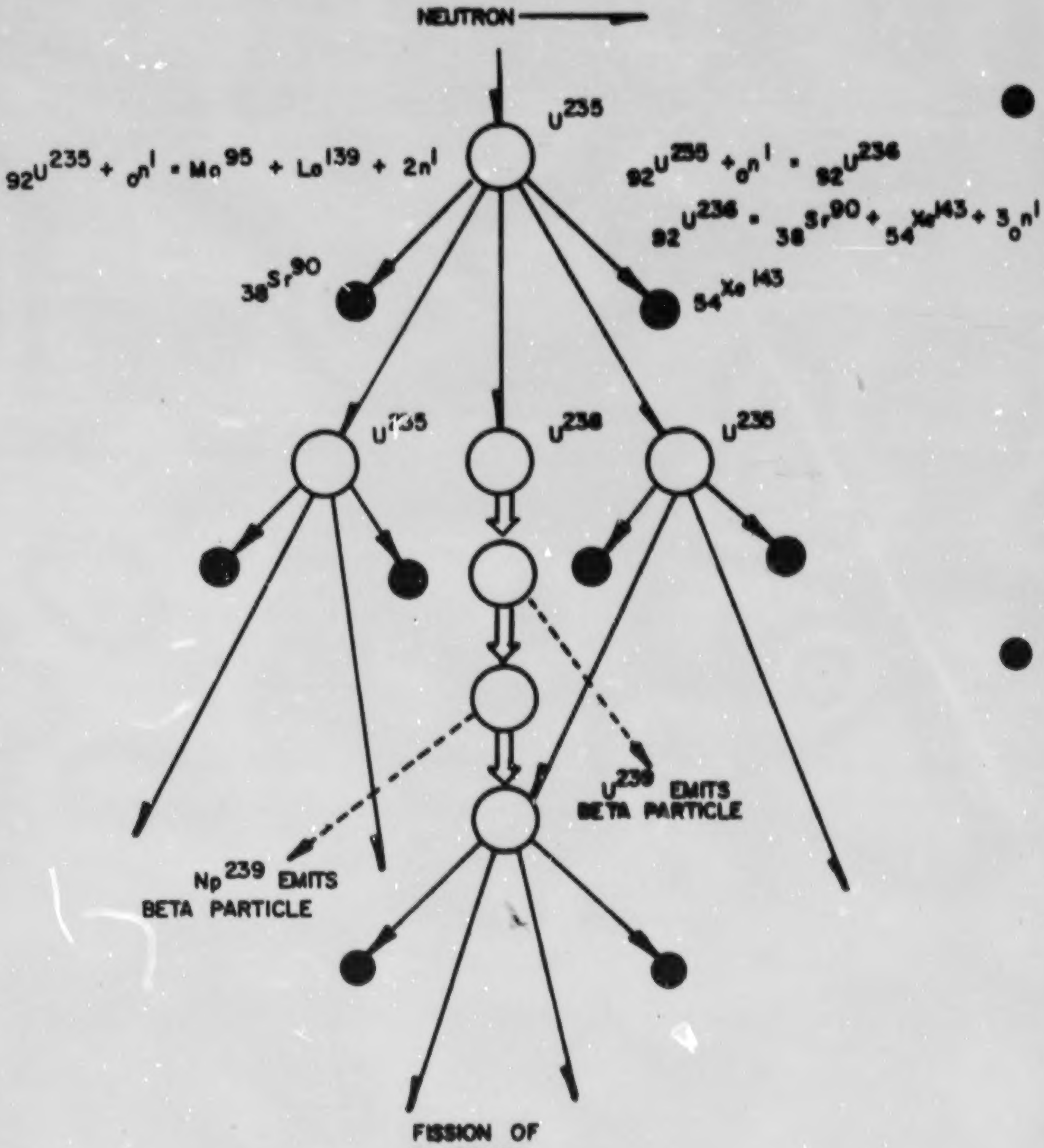

NEUTRON
U^{235}
$_{92}U^{235} + {}_0n^1 = Mo^{95} + La^{139} + 2n^1$
$_{92}U^{235} + {}_0n^1 = {}_{92}U^{236}$
$_{92}U^{236} = {}_{38}Sr^{90} + {}_{54}Xe^{143} + 3\,{}_0n^1$
$_{38}Sr^{90}$
$_{54}Xe^{143}$
U^{235}
U^{238}
U^{235}
U^{239} EMITS BETA PARTICLE
Np^{239} EMITS BETA PARTICLE
FISSION OF PLUTONIUM Pu^{239}

FIG. 2 FISSION OF URANIUM

to the energy which is required to "bind" the nucleus together--hence "binding energy".

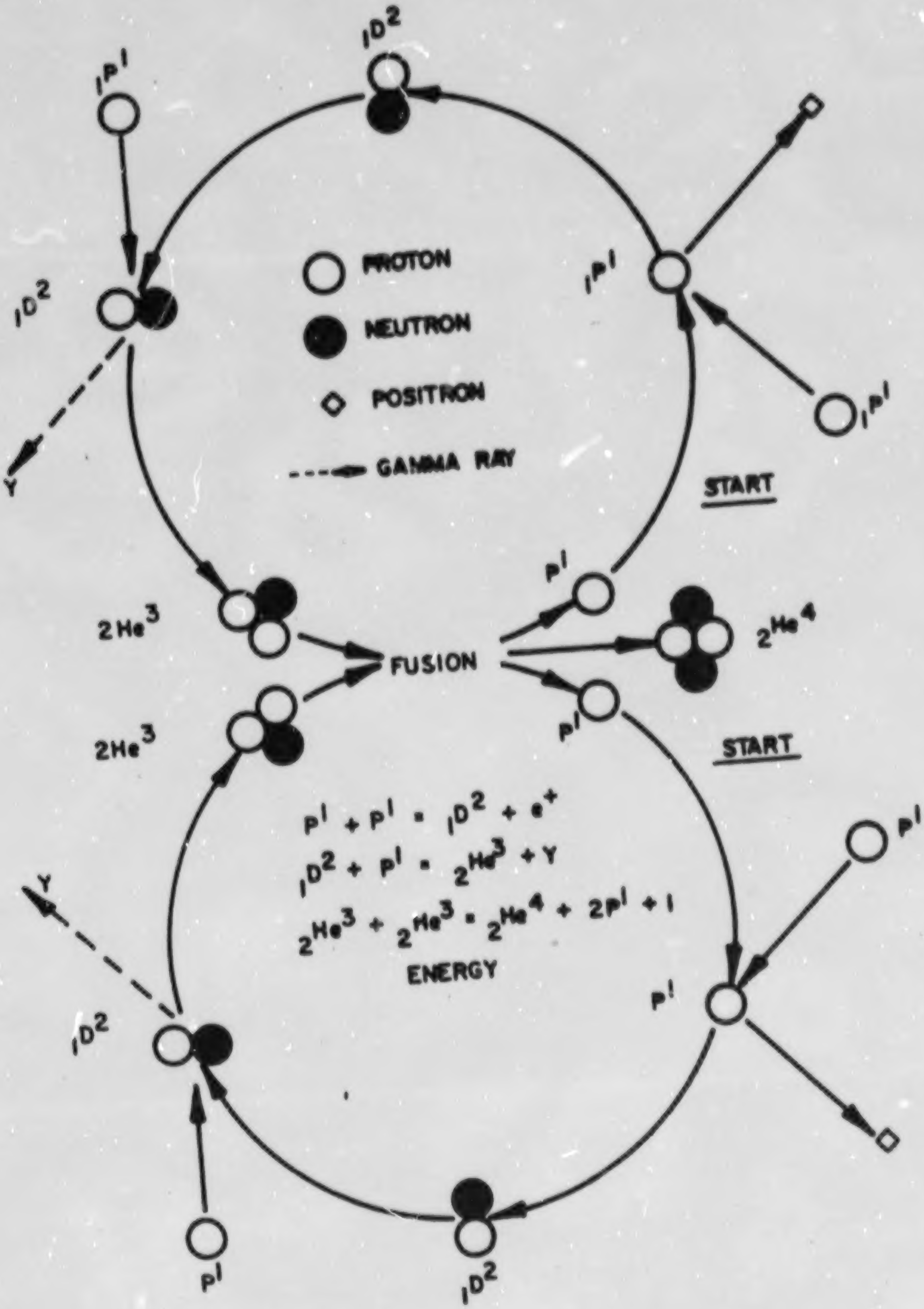
After a fission process takes place, the sum of the masses of all the resultant particles is less than the mass which was present at the beginning of the reaction. This difference in mass appears as energy according to Einstein's mass-energy and appears primarily as heat.

In a reactor, the fission process is controlled to maintain a steady production of thermal energy. This is done by "moderating" the neutrons which bombard the uranium 235 nuclei. If the reaction starts to slow down, more neutrons are allowed to enter the U-235; should the reaction begin to take place too rapidly, the neutrons are absorbed in a non-reacting material.

iii. The Fusion Process

The fusion reactor, or a controlled fusion reaction on the scale necessary to produce electrical power has not yet been developed. However, because of the enormous potential of this type of energy, a minimal understanding is desirable.

In the fission process "light" elements are formed from "heavy" elements, with an energy release. The fusion process as the name implies does just the opposite; lighter elements are fused together, forming heavier elements. (See Fig. 3). Where those elements which are fissionable are either scarce or require sophsiticated technology for their preparation, fusion fuels are


$_1D^2$
$_1P^1$
$_1P^1$
$_1D^2$
PROTON
NEUTRON
POSITRON
GAMMA RAY
γ
$_1P^1$
START
P^1
$_2He^3$
FUSION
$_2He^4$
$_2He^3$
P^1
START
P^1
P^1
γ
$_1D^2$
P^1
$_1D^2$

$P^1 + P^1 = {}_1D^2 + e^+$

${}_1D^2 + P^1 = {}_2He^3 + \gamma$

${}_2He^3 + {}_2He^3 = {}_2He^4 + 2P^1 + 1$

ENERGY

FIG. 3 FUSION

almost as plentiful as the water around us.

The essential fuel for fusion is a form of hydrogen, called heavy hydrogen or "deuterium", that exists in all water. For every 6500 atoms of ordinary hydrogen in water there is one atom of deuterium. In theory, the fusion of the deuterium in one gallon of water would produce energy equivalent to that obtainable from the combustion of 3000 gallons of gasoline. Since it costs, with today's technology, about 4¢ to extract all the deuterium from a gallon of water, the enormous potential of this type of power becomes clearly obvious.[35] It has been estimated that the fusion fuel reserves found in the oceans would satisfy the world's current rate of power consumption for billions of years![36]

However, as bright as the prospects for the utilization of fusion power appear, extremely difficult technological problems must be solved before this "ultimate" potential source of power can become a reality. Before discussing these problems, a further look at the fusion process is desirable.

The energy source of the sun and other stars in all probability appears to be the fusion of ordinary hydrogen. It was stated earlier that the essential fuel for fusion on earth is deuterium, an isotope of ordinary hydrogen. An isotope of an atom is a different form of that type of atom. What distinguishes an isotope of an element from an ordinary atom of that element is the number of neutrons in its nucleus. In the case of hydrogen, the nucleus of the ordinary atom, or most common atom consists of one proton. The deuterium nucleus contains one proton and one neutron. There is yet another form of a hydrogen atom, tritium. The tritium nucleus, called a triton (T) is composed of one proton and two neutrons. This isotope is radioactive and is very rare in nature.

iv. The Fusion of Deuterium and Tritium

Since deuterium is relatively abundant and cheap, the use of this isotope as the fuel for fusion is most desirable. Two reactions of this type are known: (see Fig. 4)

(1) $${}_1D^2 + {}_1D^2 \longrightarrow {}_2He^3 + {}_0n^1 + 3.2 \text{ MeV}$$

Symbolically, the above reaction means that two deuterons (deuterium nuclei) interact (fuse) to form an isotope of helium with the resultant release of a neutron and 3.2 million electron volts of energy.* The second reaction:

(2) $${}_1D_2^2 + {}_1D^2 \longrightarrow {}_1T^3 + {}_1H^1 + 4.0 \text{ MeV}$$

two deuterons reacting to form a triton, proton and releasing 4.0 million electron volts of energy leads to yet another reaction:

(3) $${}_1D^2 + {}_1T^3 \longrightarrow {}_2He^4 + {}_0n^1 + 17.6 \text{ MeV}$$

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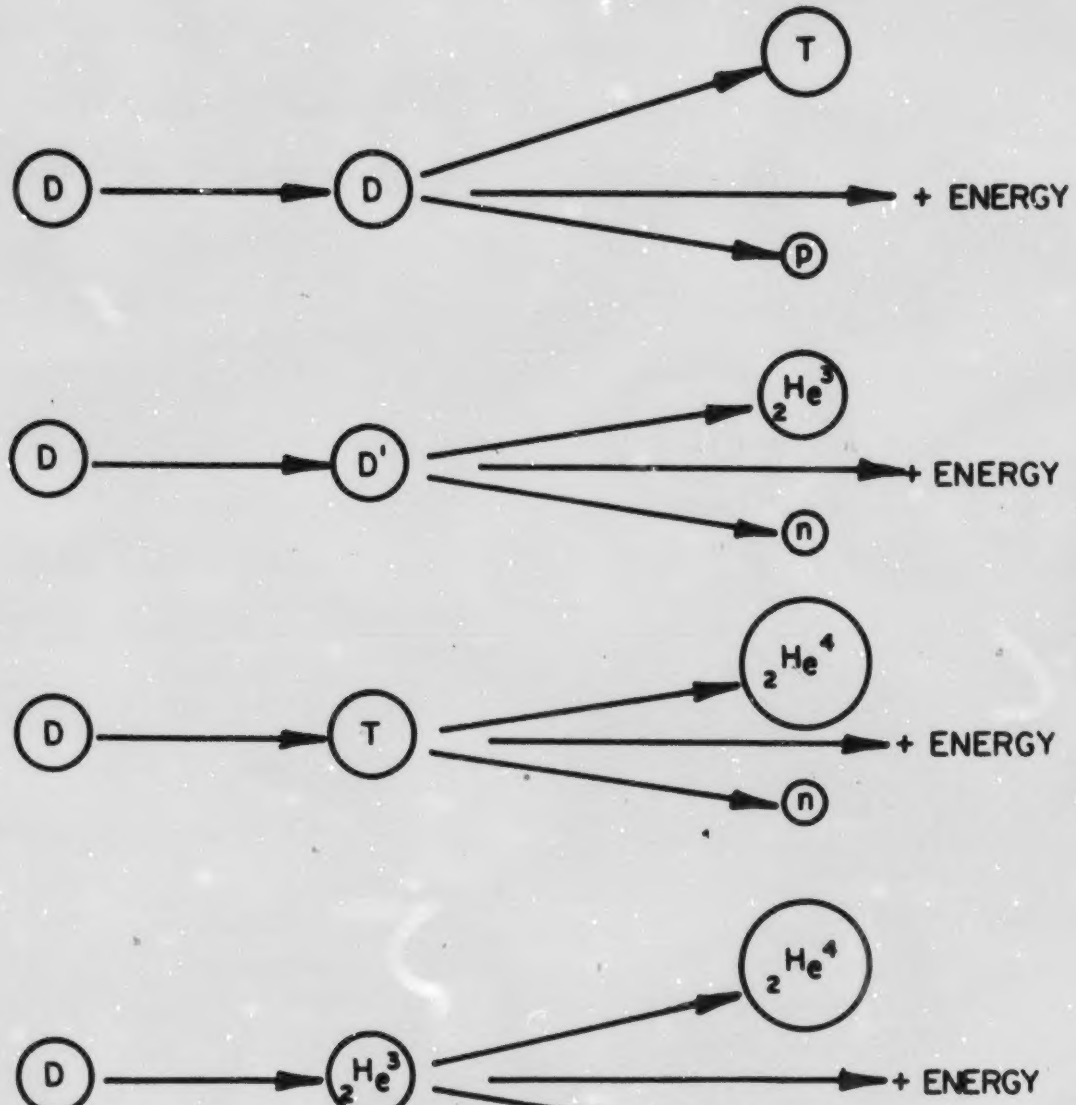
*The electron volt is a unit of energy whose definition arises out of the motion of a charged particle through a difference of potential. In thinking of the fusion process as a source of thermal energy for the production of electrical power, it may be more convenient to think of the electron volt in thermal energy units, or calories. One MeV (MeV is the symbolic representation for one million (10^6) electron volts) is approximately equal to 3.8×10^{-14} cal.


D
D
T
+ ENERGY
p
D
D'
${}_2He^3$
+ ENERGY
n
D
T
${}_2He^4$
+ ENERGY
n
D
${}_2He^3$
${}_2He^4$
+ ENERGY
p

D = DEUTERIUM (HEAVY HYDROGEN), ${}_1H^2$
T = TRITIUM (HEAVY HYDROGEN), ${}_1H^3$
n = NEUTRON, ${}_0n^1$

p = PROTON, ${}_1H^1$
${}_2He^3$ = HELIUM NUCLEUS (ISOTOPE)
${}_2He^4$ = HELIUM NUCLEUS

FIG. 4 DEUTERIUM - DEUTERIUM FUSION

or the triton formed in reaction 2 combines with another deuteron forming an ordinary helium nucleus, a neutron and releasing 17.6 million electron volts of energy.

Since these three reactions occur sequentially, the net reaction, starting with two deuterons (equation 1) releases 3.2 + 4.0 + 17.6 = 24.8 MeV. This leads to the conclusion that the complete fusion of the deuterons in one gram of deuterium will yield 5.6×10^{10} calories. Therefore, since a gallon of ordinary water contains one-eighth of a gram of deuterium, its energy equivalence is 7×10^{9} calories, which is approximately equal to the combustion energy of 300 gallons of gasoline, as stated earlier.

The amount of deuterium estimated to be in the oceans is 4.5×10^{19} grams. With a fusion energy content of 2.5×10^{30} calories, or approximately 3×10^{20} kilowatt years.* At a world-wide energy consumption rate of 5×10^{9} kilowatt-years, (1964 figure) these reserves should last billions of years.[37]

However, to achieve self-sustaining fusion, the nuclei have to possess very high energies. Thermo-nuclear reactions are those fusion reactions which are brought about by means of high temperatures. Temperatures of 40 million degrees Kelvin** and 45 million degrees Kelvin would be required to sustain D+D and D+T reactions, respectively.[38]

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*A kilowatt (one thousand watts) is a unit of power, which is the rate of energy consumption. Multiplying kilowatts times a year (kilowatt year) yields the amount of energy consumed in the period of a year.

It should be obvious to even the least scientifically oriented person that temperatures of such magnitude (the temperature of the sun's interior is 15 million degrees K) cannot be contained in the normal sense of the term. Any container would be changed to a gaseous state if it were subjected to sustained temperatures of much less magnitude for any appreciable time.

Also, at such temperatures, the electrons are stripped off from atoms forming positive ions (atoms without the required number of electrons surrounding the nucleus). The gas thus formed is called a PLASMA. Since the plasma is electrically charged it exhibits magnetic properties.

These magnetic properties offer the potential for confining the gas (deuterons and tritons) and achieving the high temperature necessary for the fusion reaction to take place.

Moving charged particles generate a magnetic field around the path of their motion. Since magnetic fields have attractive or repulsive tendencies, depending on their respective directions, it is possible to "contain" moving charged particles in a closed path due to the interaction of their field and an externally applied

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** The Kelvin scale is used to measure "absolute" temperature. The centigrade (Celsius) equivalent is found by subtracting 273 from the Kelvin reading or K = C + 273.

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field. Various shapes of external magnetic fields have been attempted to produce the desired effect of creating a "magnetic bottle" in which a sustained fusion reaction can take place.

Controlled fusion reactions have been achieved recently on a laboratory scale, although for an extremely short duration. Research is currently underway in this area with the expectation that a controlled thermo-nuclear reaction producing electricity can be achieved by the end of this decade.

D. Tidal Power

Tidal power can be obtained by controlling the tidal filling of a bay or estuary by means of a dam.

Using the tides as a source of power was considered as far back as the 1930's. A joint venture of the American and Canadian Governments was then discussed (the Passamaquoddy Project) which would harness some of the energy of the tides in the Bay of Fundy, between Maine and Canada. Fully developed, the proposed site would develop 300 megawatts of power, which is about one third of that which a large fossil fuel steam driven turbo generator can develop. A recent renewed interest has been exhibited in the Passamaquoddy Project.

One full scale tidal power plant has been built to this date. It is located on the Rance estuary on the coast of France, and its capacity in 1966 (when opened) was 240 megawatts, with a planned ultimate capacity of 320 megawatts.[39]

Although harnessing the tides as a source of electrical power has a thermal advantage (no waste heat as a resultant product), it is not the sole answer to the problem. First, ecological changes which will occur as a result of sustained flooding of tide-water areas must be reckoned with, and second, the total energy available is small, relative to the need.

It has been estimated (and all estimates of this nature are subject to challenge) that the harnessing of all favorable sites in the United States would yield about 100 GW (a GW, gigawatt or 10^9 watts). A recent estimate by Westinghouse indicates that U.S. utilities must add more than 1,000 GW of new capacity, or ten times the total amount available from tidal sources, between 1970 and 1990.[40]

E. Geothermal Power

The term "geothermal" refers to the internal thermal energy of the earth. Utilization of this heat from the earth's molten core and from nuclear and chemical reactions in the earth's crust is yet another means of producing electrical power.

Geothermal power plants are presently in operation in Italy, California, the Soviet Union, New Zealand, and Iceland. Although the entire interior of the earth is considered a potential heat source, only volcanic sources are significantly exploited at this time.

A geothermal plant in Italy, in operation since 1904 has a current capacity of 370 megawatts. The two other major geothermal power producers are The Geysers in Northern California, generating 82 megawatts in 1969 with 400 megawatts projected for 1973, and Wairakei in New Zealand, with a capacity (believed to be the maximum for the site) of 290 megawatts.[41]

According to Donald E. White[42] of the U.S. Geological Survey, the total exploitable geothermal energy ranks comparably with tidal energy as a potential source of electricity. However, what is considered unexploitable now, may, for a variety of reasons, new technology being one, become viable sources in the future.

F. Solar Energy

Increased use of solar energy, the continuously radiated energy from the sun to the earth, is an attractive alternative for two reasons:

1. Although its supply is not infinite in fact, it is in effect. The earth is truly a satellite, a fellow traveler of the sun -- when the sun "goes out" so does the earth.
2. Where the burning of fuel for the purpose of electrical power production injects another form of energy -- heat -- into the environment, solar energy would not, it would normally appear as heat.

The amount of sun power intercepted by the earth is about 100,000 times as great as all of the present world's electrical generating capacity.[42] However, this energy is so diffuse, that collection poses an extremely difficult problem.

Aden and Marjorie Meinel of the University of Arizona, suggest, in a report to the Arizona Power Authority, that efficient collection of 14 per cent of the sunlight falling on the western desert regions in the United States, could result in the production of 1,000 GW of electrical power --- approximately that amount of additional power needed between now and 1990.[43]

Various schemes for utilization of solar energy are being discussed. Most rely on a storage system, because of the variation of incidence of sunlight. Basically, methods based upon storage operate as follows. Sunlight would be collected and focussed on a point where a heat exchanging fluid would be heated. The heated fluid would be pumped to a heat storage system, possibly molten salts at 1000°F. Another heat exchanger would be used to generate steam at the same temperature, the steam then to be used to drive turbines.

According to the Meinels, a solar power plant of 1,000 megawatts capacity would require a thermal storage tank of 300,000 gallon capacity and solar collectors of slightly more than one square mile in area.[44]

Peter E. Glaser of Arthur D. Little, Inc. has a space age oriented proposeal for solar power. His system would utilize the panel of solar cells in an orbit 22,300 miles above the earth.

At that distance the period of orbit would be equal to that of the earth' s rotation, and panels would be exposed to continuous sunlight.

The solar cells would convert the sunlight directly to electricity. The electrical energy would be converted to microwave (electromagnetic) energy for transmission to earth for reconversion to electricity.[45]

Since much of the technology needed for this type of system has yet to be developed, from the direct conversion solar cells to the space shuttle needed to construct the orbital "solar antenna", it is obvious that Glasers' scheme is one for the future -- at best.

III. WHERE DO WE GO FROM HERE?

Dr. Hyman Rickover, called by some "the father of our nuclear navy", has referred to this era of time as "The Fossil Fuel Age". The implication being that this, like the "Ages" before, Stone, Ice, etc., will pass into eternity. He has estimated that the total amount of fossil fuels used before 1900 would be consumed in less than a five year period at the current rate of use.

The picture painted of the energy crisis is indeed somber. What story does the painting depict is the question that remains to be answered.

The history of power generation has, like that of many of the

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manufacturing industries has been one of maximizing production while minimizing costs. To a profound extent, this philosophy has led to a rapid reduction of natural resources of virtually all types. What once was discarded as waste in a manufacturing process may now be considered as a usable-grade ore. Sources of minerals once passed by because of relatively low yield are now being exploited. "Recycle" is becoming the watchward of our time.

In the not too distant past, cost factors in production did not include the accompanying deleterious, sometimes disastrous effects on the environment.

It was stated earlier that a possible alternative to current methods of power production might be the construction of smaller multi-faceted plants (i.e., a combination of various types - nuclear, fossil fueled, hydroelectric, solar, etc., the types being dependent upon geographic location) as integral parts of residential or industrial complexes. This could enable the use of what is, under the present system, waste heat. Centrally located power plants could reduce the distance this energy would have to be transported, thereby making its use feasible.

This would be doubly beneficient - reducing the consumption of fuel for heating purposes by using the waste heat, and reducing the environmental thermal load. The latter benefit can be ascribed to several factors, two being:

1) less energy will be converted into heat, and

2) the thermal imbalance introduced by the conversion of energy will be spread over a larger area, thus making its absorption into the ecosystem less dramatic.

The argument against this radical departure from present practice is quite obvious - cost!

It is clear even to those far removed from technology, that it costs more to build two - or more - smaller plants rather than one -- from the amount of land necessary for the site/s to the procurement and transportation of the materials required. It is also quite probable that more personnel will be required to operate and maintain multiple locations. I'm sure there are a thousand ways whereby the increased costs of such a system could be demonstrated by those whose responsibility it is to plan and build.

But, one factor has consistently been excluded--that of the environmental effect and resource depletion. The reasons for this exclusion are varied, but complexity is surely obvious. Couple complexity with no apparent need - no solution is possible, because in effect, no problem exists.

However, since necessity is the mother of invention, and international concern over industrial environmental effects is rapidly mounting, rest assured that the new cost factor will evolve quantitatively.

This will mean a higher cost to the consumer. However, it will not be a new cost, but for the first time, it will be direct. A price has been paid for some time by all, but in varying proportions. Rivers, lakes and harbors have been closed to fishing and recreational use due to various types of pollution - industrial and residential. To be denied their use certainly exacts a price. What hasn't been done, and quite probably can't be done, is to afix a specific figure.

Realizing increased direct costs to be inevitable, what courses of action are open? First, if widespread recognition and understanding of this necessity were achieved, the development of the instruments of change and their means of implementation would be enhanced. On the other hand, ignorance of the problem by a large segment of the population can only result in solution by governmental imposition, with all the delay and bitterness concomitant with it.

An enlightened, concerned, and involved citizenry is not only desirable--it is necessary.

And finally, because of our inherent acceptance of the use of fossil fuels as the primary source of power production, development of alternate methods has lagged. Any major departure from our near total dependence upon fossil fuels is made more difficult by the general attitude towards research.

Pure research is quite costly both in manpower and instrumentation. It is easy to put off since its cost, in general, cannot be offset by immediate returns. That is, there is usually a considerable time lapse between expenditures for research and any profits which may ultimately result. Therefore, in order to support research in any given sector, profits must be reduced or prices for currently produced products increased, or both.

American industry, again, generally speaking, has utilized a dangerously small proportion of its overall budget for research purposes. In the power industry vast research and development programs must be continually maintained, in order to meet the ever increasing demands for electricity.

IV. LABORATORY EXERCISES

Laboratory Exercises One

MEASUREMENT AND DENSITY

Purpose: The student will gain a familiarization of the Metric System of Units through the use of several measuring instrments. Densities of several substances will be determined and compared against accepted values.

Equipment and Apparatus:

1. Vernier Calipers (Student Grade)
2. Micrometer Calipers (Student Grade)
3. Meter Stick
4. Platform Balance
5. Graduated Cylinder

6. Assorted samples to be measured. (cylindrical, rectangular solid, irregular.)

Procedure:

First examine the various instruments with which measurements are to be taken. See if you can deduce how they are to be read. If you cannot, consult the instructor.

Determine the dimensions of the various samples, using each measuring instrument where possible. Record the data in tabular form in your Laboratory Notebook, on a page titled, DATA.

Using a platform balance, determine the record the mass of each specimen.

Calculate the volume of each specimen and record in tabular form on a page titled RESULTS. Using the equation d=M/V (density is equal to the mass of a substance divided by its volume) calculate the density of each substance and record in same the table as the volumes.

INDIRECT MEASUREMENT

You will now determine the densities of the samples indirectly.

Archimedes discovered that submerged objects displaced a volume of water which was equal to the volume of the submerged object. Therefore, by measuring the volume of the water displaced by an object, the volume of that object can be ascertained.

Procedure:

Partially fill a graduated cylinder with water. Record the level. Immerse object whose volume is to be determined. Record the level to which the water has risen.

The difference between these two levels is displaced water hence, the volume of the object. Repeat for all samples.

Conclusions:

You have taken various measurments using different instruments. Write a short critique of the exercise you have performed, being sure to touch on the following questions:

1. Were your measurements exact?
2. Which were the most accurate?
3. What sources of error (specific) are involved?
4. Can the volume of a substance lighter than water be found by the displacement method? If so, how?

Most physics textbooks contain tables which list the densities of the samples you used. Look them up and record in the table on your Results page, in a column entitled "accepted values."

Determine the % error between your findings and the "accepted values" in the following manner:

% error = accepted (standard) value - experimental value times 100% standard value.

Do you think your results are acceptable? Why or why not?

Laboratory Exercise Two

POWER

Purpose: To acquaint the student with the quantitative meanings of energy, work, and power.

Energy is defined as the ability or capability of doing work. The work referred to here is quite different than that which is commonly thought of outside of scientific circles. In order to be quantitative (to be able to measure, or associate numbers with a quantity) a specific definition is needed.

In physics, work is defined as the product of a force and the distance over which that force acts. For example, in order to life a weight of 20 lbs. straight up, a force equal to the weight must be applied. If the weight is raised, say, 5 feet, the force has acted over a distance of 5 feet. Therefore, according to the definition, the work done is 20 lbs. times 5 feet, or 100 lb. ft. or by convention, 100 ft.·lbs.

No mention has been made so far as to the time required to raise the weight. This is because the amount of work done is independent of the time over which it is done.

This is where power comes in. Quantitatively, power is defined as the time rate of doing work. Or, more simply, the work done divided by the time over which it was done. That is

power = work/time

Let's say the work done in the previous example was done in 10 seconds.

The power therefore was $\frac{100\ \text{ft}\cdot\text{lbs}}{10\ \text{sec}}$ or $\frac{10\ \text{ft}\cdot\text{lbs}}{\text{sec}}$. If the work were performed in 5 seconds, power = $\frac{100\ \text{ft}\cdot\text{lb}}{5\ \text{sec}}$ or $\frac{20\ \text{ft}\cdot\text{lb}}{\text{sec}}$.

The unit of power commonly used in our system of units is the horsepower. It is defined as $\frac{550\ \text{ft}\cdot\text{lb}}{\text{sec}}$ since it was determined that an average horse could work at that rate for a sustained period of time.

In this exercise, you will determine the horsepower you develop in climbing stairs. The work you do is the raising of your weight from the bottom to the top.

Equipment and Apparatus:

1. yard stick
2. stop watch
3. scale (to determine weights of students).

Procedure:

1. determine and record your weight.
2. Measure and record the height of the staircase.

Then climb the stairs at your normal rate, measuring and recording the time required. Then repeat, climbing at a hurried rate and finally, climbing as fast as you can. NOTE: IF FOR REASONS OF HEALTH YOU ARE NOT TO OVERLY EXERT YOURSELF, OMIT CLIMBING THE STAIRS AT ANY ACCELERATED RATE!

Now calculate and record the horsepower you developed in each of the trials.

$$\text{power in H.P.} = \frac{\text{Force times } \underline{\text{vertical}} \text{ distance travelled}}{\frac{\underline{550 \text{ Ft lb}}}{\text{sec}} \quad \text{time required}} \text{ H.P.}$$

Note for previous example

$$\text{power in H.P.} = \frac{20 \text{ lb} \times 5 \text{ ft}}{550 \frac{\text{ft} \cdot \text{lb}}{\text{sec}} \times 5 \text{ sec}} \text{. H.P.} = .036 \text{ H.P.}$$

For the trial in which you climbed the stairs at a normal rate, calculate and record the ratio of your weight to horsepower. Compare this figure with that of the automobile you drive.

Laboratory Exercise Three

SPECIFIC HEAT

Purpose: This exercise is designed to acquaint the student with the concept of specific heat. The specific heat (c) of a substance can be defined as the amount of heat necessary to raise the temperature of a unit mass of the substance one degree.

What is implied in the definition is that identical masses of different substances will require different amounts of heat to raise their temperatures an equal amount, or these substances can give off different amounts of heat while cooling through an equal temperature range.

In this exercise, various metallic samples will be heated in a beaker of boiling water. After they have reached the temperature of the boiling water (equilibrium) they will be placed in an insulated container of cooler water.

The heat gained by the samples in the boiling water will be transferred to the cooler water, causing its temperature to rise.

By recording the necessary data and using the appropriate relationships, the specific heats of the various samples will be determined.

Equipment and Apparatus:

1. burner, stand, and beaker
2. various metallic samples whose specific heats are published
3. thermometers
4. calipers (to remove samples from boiling water)
5. styrofoam cups
6. balance

Procedure:

1. place samples in boiling water, leaving them in sufficient time for equilibrium to be achieved.
2. determine and record the mass of styrofoam cup.
3. place enough water in cup so as to cover one of the samples.
4. determine and record mass of water in cup.
5. determine and record the temperature of the water in the cup.
6. read and record temperature of boiling water.
7. remove a sample and quickly place it into styrofoam cup.
8. gently stir the water and record the new temperature.

9. measure and record the mass of the sample.
10. replace sample into boiling water.
11. repeat steps three (3) through ten (10) for all samples.

Calculations:

The heat "lost" by the heated sample is equal to the heat "gained" by the cool water (excluding extraneous losses), or symbolically,

$$Q(\text{lost}) = Q(\text{gained})$$

The heat "lost" or "gained" by a substance can be found by the expression

$$Q(\text{lost or gained}) = Mc\Delta t$$

where M is the mass of the substance
c is the specific heat or the substance
Δt is the temperature change it has undergone.

Therefore, for this exercise

1 $Mc\Delta t$ (of sample) = $Mc\Delta t$ (of cool water).

Knowing the specific heat of water to be 1 calorie per degree Celsius (Centigrade) per gram, the only unknown in equation 1 is the specific heat of the unknown.

Determine the specific heats of the unknowns.

Refer to physics texts and find the published values for these specific heats. Compare your experimental results with the published values by finding the % error for each. Record in tabular form in Results page.

Write a critique discussing sources of error. Be specific where possible.

Laboratory Exercise Four

MECHANICAL EQUIVALENT OF HEAT

Purpose: The purpose of this exercise is to demonstrate to the student the direct relationships between mechanical energy and thermal energy, heat.

Most people know to varying degrees, that there exists a relationship between work (in the scientific sense), and heat. This can easily be demonstrated. Press your hands firmly on the desk or table top. Now slide your hands. How do they feel? Do it again, only pressing harder. Is there any difference?

Is work being done? The definition of work is satisfied. A force of friction is created between the table top and your hands. This force is then moved through a distance (you moving your hands). Therefore, work is done. And--

Thermal energy is produce - your hands get warm. This experiment will demonstrate the existence of a quantitative relationship between the work done and the thermal energy produced.

Equipment and Apparatus:

Mechanical equivalent of heat apparatus similar to that available from Sargent-Welch or Klinger Scientific Apparatus Co. This apparatus consists of:

1. a copper calorimeter in the shape of a drum

2. a thermometer
3. a copper band
4. a 5 kgm mass
5. a length of cord

Also needed but not included

1. a meter stick
2. platform balance
3. an additional thermometer.

Procedure:

Set up apparatus according to the diagram which accompanies it.

Adjust the copper band and cord such that the band is wrapped around the drum-calorimeter 4-5 times, and the steady turning of the crank will raise the 5 kgm mass off the floor and keep it steadily suspended.

Contemplation will show that the frictional force between the copper band and the drum is just equal to the weight of the suspended mass in this configuration, and that turning the crank is effectively moving that frictional force. Now, disassemble the apparatus. You will reassemble it exactly as it was as you follow the following sequence of steps.

1. Measure and record the mass of calorimeter and copper band (exclude thermometer).
2. Fill calorimeter with 50-60 grams of water which is approximately

room temperature. (record this temperature).

3. Replace the calorimeter on to the apparatus.
4. Turn crank at a stead rate for 200 turns.
5. Read and record temperature of the water in the calorimeter.
6. Determine and record the circumference of the calorimeter. (This can be done by appropriately fastening the copper band to the calorimeter holder, measuring the height the 5 kgm mass is above the floor; turning crank one (1) complete revolution; remeasure the height of the mass. The circumference is the difference of the two heights).

Calculations:

Heat is developed by the work done by the frictional force between the copper band and the drum, much in the same manner as when you rubbed your hands. This frictional force moved through a distance of 200 circumferences of the drum. Therefore, the work done is

Work = 200 rev. times (# of cm/rev) times w (weight)

$$w \text{ (weight)} = 5 \text{ kgm} \cdot 9.8 \text{m/sec}^2 = 49.0 \text{ nt.}$$

the quantity of work done, measured in the metric system will be in joules (1 joule = (one newton) times (one meter). To find the mechanical equivalent of heat (J) or how much heat one could expect to gain from a specific amount of work, the amount of heat produced must be determined.

The heat Q is found by

$$Q = (M_{cal} + M_{cu}) c_{cu} \Delta t + M_{H_2O} C_{H_2O} \Delta t + 0.0008^{*} \Delta t$$

where

M_{cal} is the mass of calorimeter in

M_{cu} is the mass of copper band

M_{H_2O} is the mass of water in the calorimeter

c_{cu} is specific heat of copper

c_{H_2O} is specific heat of water

Δt is change in temperature of calorimeter and water

.0008 is a correction factor for heat absorbed by thermometer (all masses must be in kilograms).

Therefore the mechanical equivalent of heat, J can now be found

$$J = \frac{W \text{ (work)}}{Q},$$

and its units will be joules per calorie.

Compare your results with those of your classmates and the accepted value.

Write a critique describing possible sources of error.

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[*] This value pertains to Klinger apparatus.

V. REFERENCES

1. Abrahamson, Dean. Environmental Cost of Electric Power. Scientist's Institute for Public Information, New York, 1970, pp. 3-5.

2. Ibid.

3. "Technology for Society, The Energy Famine," Machine Design, March 4, 1971, p. 21.

4. "The Dam The U.S. Wouldn't Build," U.S. News and World Report LXVII (December 29, 1969), p. 66.

5. Sterling, Claire. "The Aswan Disaster," Our Chemical Environment, San Francisco: Canfield Press, 1972, p. 84.

6. Ibid, pp. 86-90.

7. Op. Cit., Dean E. Abrahamson, p. 18.

8. Saunders, Claude M. "The Conservation of Energy', Scientific American, Vol. 224, September 1971, pp. 149-160.

9. Op. Cit., Dean E. Abrahamson, p. 18.

10. "Oil," The New York Times, February 17, 1971, p. 25.

11. Op. Cit., "The Energy Famine," p. 25.

12. Op. Cit., "Oil", p. 25.

13. Op. Cit., "Oil", p. 25.

14. "Press Release," Office of the White House Press Secretary, June 4, 1971, p. 1.

15. Levenbach, R., Ed., "Problems of Electric Power For The Future," Sworthmore College, Dept. of Engineering, Sworthmore, Pa., September 21, 1970, pp. 9-10.

16. Op. Cit., Dean E. Abrahamson, p. 23.

17. "Energy Crisis: Are We Running Out?" Time, Vol. 99, (June 12,1972), p. 52.

18. Op. Cit., Dean E. Abrahamson, p. 18.

19. Ibid., p. 21.

20. Ibid., p. 23.

21. A Study and Recommendations by the Committee on Resources and Man of the Division of Earth Sciences, National Academy of Sciences ' National Research Council, with the cooperation of the Division of Biology and Agriculture, Preston Cloud, Chairman, Resources and Man, San Francisco, W.H. Freeman, 1969, p. 228.

22. Op. Cit., Press Release, p. 3.

23. Op. Cit., Dean E. Abrahamson, p. 12.

24. Federation Radiation Council Staff Report. May 1960.

25. Quimby, Edith H., and Beitelberg, Seiger. Radioactive Isotopes in Medicine and Biology, Lea & Febiger, 1963, p. 29.

26. Ibid., p. 30.

27. Ibid., p. 31.

28. Ibid., p. 37.

29. Ibid., p. 104.

30. Ibid., p. 108.

31. Ibid., p. 101.

32. Ibid., p. 142-143.

33. Op. Cit., Dean E. Abrahamson, p. 13.

34. Ibid.

35. Atomic Energy Commission. Controlled Nuclear Fusion, p. 3.

36. Ibid., p. 7.

37. Ibid.

38. Ibid., pp. 9-12.

39. Hubbert, M. King. "The Energy Resources of the Earth," Scientific American, Vol. 224, (September, 1971), p. 67.

40. Op. Cit., Claude M. Summers, p. 157.

41. Op. Cit., M. King Hubbert, p. 67.

42. Bengelsdorf, Irving. "Are We Running Out of Fuel?", Our Chemical Environment, J.C. Giddings & M.B. Monroe, Eds., San Francisco, Canfield Press, 1972, p. 290.

43. Op. Cit., Claude M. Summers, p. 158.

44. Ibid.

45. Ibid., pp. 158-159.

SUGGESTED READINGS

Cook, Michael C. *Energy in the United States*, *1960-1985*. New York Sartarius Press, 1967.

Environmental Effects of Producing Power, Part I. U.S. Government Printing Office, Washington, 1969.

Johnson, Huey D., Ed. *No Deposit - No Return*, *Man and His Environment: A View Toward Survival*. Reading, Mass. Addison-Wesley, 1969.

Man's Impact on The Global Environment. Cambridge, Mass. MIT Press, 1970.

Turk, A., Turk, J. and Wittes, J. *Ecology Pollution Environment*. Philadelphia. W.B. Saunders Company, 1972.

NOISE POLLUTION

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"Partly because noise cannot be seen and can be eliminated by turning off the source and partly because the full effects of noise on human beings are still open to question, it has not received the degree of social concern that has recently been given air and water pollution. Yet noise has disrupted the environment just as surely as other forms of pollution and will require commensurate attention."

James M. Kramon, "Noise Control: Traditional Remedies and a Proposal for Federal Action". Harvard Journal on Legislation, Volume 7, (1970).

PREFACE

This teaching module contains all the information needed to teach a three to four week segment of a course dealing with problems of the environmental pollution.

The basic sub-division of the module are as follows: -

1 - Introduction

2 - Physics of Sound

3 - Measurement of Sound

4 - Physics of the Ear

5 - Audiometry

6 - Medical Effects of Noise

7 - Legal Aspects of Noise

8 - References

The sub-divisions are arranged presumably as they will be presented.

It is the intention of the author that the unit called "Introduction" be given to the students at the outset so that the students are made initially aware of the overall problems of noise pollution. At this point the class could be divided into committees and each given a sub-division to research and report back to the class. Using this as a spring board the instructor could take one committee report each time as a basis of a unit. There are sample references in the back of the module so that the instructor could make a copy of the list and distribute it to the committees.

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I. INTRODUCTION

Sound is all around us. It is very important in our lives. It is one of the most important means of communication - it can be a source of pleasure. On the other hand it can be a source of discomfort and distraction. This unwanted sound is called noise. The word noise is derived from the same Latin root as the word nausea - defined as a discomfort of the stomach. One can see the connection between noise and the feeling of discomfort it provokes. In fact evidence compiled through expanded medical research, indicates that noise constitutes a health hazard, not only as a cause of deafness, but as it relates to other aspects of health. It is interesting to note that much of the sound that bombards our ears today is considered by those responsible for its emission as pleasant rather than noise. For example, rock'n'roll groups and hi-fi enthusiasts use high powered electronic amplifiers which are a definite threat to the hearing of the general public. These people are often responsible for generating sounds at levels approaching the threshold of pain.

What is noise? Previously we defined it as unwanted sound but we must expand the definition. Physically, noise is sound, but it is sound which is uninvited, unwelcome, unwanted, uncomfortable, and unhealthy.

Since noise is sound, to understand the problems presented by noise we must have a better understanding of sound. To be able to appreciate the difficulties presented by noise we must be able to answer such questions as:

What is sound?

How is it generated?

How is it transmitted?

How do we hear?

What are the physical consequences of noise?

What is being done to alleviate the problem?

Let us take each of the questions one at a time, although it is easier to consider the first three together.

What is sound, how is it generated and transmitted?

Sound is a threefold phenomena. It must have a source. All sounds are produced by the vibrations of bodies. The number of times that a body vibrates per second is called its frequency. In pianos and saxophones, for example, the sounds are produced by vibrating strings and a reed. The human voice is the result of the vibrations of the vocal cords.

Sound must have a medium to be transmitted. Most sounds are transmitted to our ears through air as a medium. However, any elastic substance whether solid, liquid or gas can transmit sound. Thus the sound of a neighbor's television is transmitted through the floors and walls of our houses or apartments. The fact that sound travels in solids is evident if we recall the old Indian trick of putting one's ear to the ground to hear if any riders were approaching.

Sound must have a detector - The Ear - The sympathetic vibration of the ear mechanism and the translation of these vibrations into electrical impulses which are interpreted by the brain as sounds.

The next question to be answered is how do we hear?

The human ear consists of three principle parts, the outer ear, the middle ear, and the inner ear. Sound energy entering the outer ear travels through the medium until it reaches the ear drum, which is caused to vibrate in response to the sound pressure. The middle ear contains three tiny bones which couple the vibrations of the eardrum to the inner ear. The inner ear, which is filled with liquid, contains the sensing element. The function of the middle ear is to transmit the sound vibrations from a gaseous medium to a liquid medium. It is in the inner ear that the sound vibrations are translated into electrical impulses which are carried to the brain by the nerves. Before we can consider the next questions we must examine how sound is measured so that we can speak intelligently about its effects.

The pressure level of sound is measured in units known as decibels, abbreviated dB and named in honor of Alexander Graham Bell. Zero decibels (0dB) is the weakest or faintest sound that a pair of young healthy ears can detect. The decibel scale has a range of 0 to 140 for normal sound measurements. The scale is not linear but logarithmic like that of the slide rule, so that 20 dB is ten times the intensity of 10 dB and 40 dB is 1000 times the intensity of 10 dB. This kind of scale is necessary because of the incredible range of sound levels that the ear is capable of handling. Some typical sound levels are shown in the table below.

	dB
Rustling leaves	20
Soft Whisper at 5 ft.	34
Window Air Conditioner	55
Normal Conversation	60
Vacuum Cleaner (Home)	70
Ringing Alarm Clock	80
Loud hi-fi in a large room	83
Beginning of hearing damage (if prolonged)	85
Heavy city traffic	92
Home lawn mower	98
150 Cubic feet air comp.	100
Air Hammer	107
Metal Cutting Saw	110
Jet Liner over head 500 ft.	115
Threshold of Pain	140

To appreciate the tremendous range of sound levels that the ear is capable of detecting we might point out that the intensity of the sound generated by a jet liner is ten billion times greater than that of rustling leaves.

What are the physical consequences of noise?

Noise affects the human in two ways. The first is the actual physical damage which it causes due to the intensity. The other is the psychological effect which eventually has more severe consequences.

While the human ear can handle an incredible wide range of sound power, it is unfortunately not immune to the effects of that power. Noise causes damage in the complex inner ear where sounds are sensed. In this tiny snail-shaped structure are microscopic hair cells that convert the mechanical motions of the sound into electrical signals which are sent along the auditory nerve to the brain. These hair like cells are easily damaged in intense noise. Allowed to rest in quiet, they can recover. But if the noise repeats itself too soon, they can be permanently damaged. Noises which are most dangerous to hearing are those which are loud, high-pitched, pure in tone and long in duration. Sharp, loud impulses noises like gunfire, are also very harmful.

Noise not only directly affects the ears, but indirectly affects other parts of the body as well, specifically the cardiovascular system. Noise increases the level of artery-clogging cholesterol in the blood, and therefore raises the blood pressure. Even moderate noises cause small blood vessels in the body to constrict and to reduce or cut off blood flow. This action called vaso-constriction reflex is one of the body's automatic ways of responding to the stress of noise. Noise has the opposite effect on blood vessels of the brain. It makes them dilate, or enlarge thereby causing a headache. Noise further threatens the heart itself by directly altering the rhythm of its beat. The heart is also made to work harder due to the constrictions of the blood vessels.

Noise affects nerves and emotions as well as the body. In certain rare forms of epilepsy, for instance, noise can trigger seizures. Sudden loud noises cause fear reaction which raise the nerves to a fever pitch. On the job, noise more often acts as an annoyance through interference with the thought processes and interposing itself in conversation. Noise triggers the Lombard effect, a reflex which makes a person speak louder. An even more subtle effect of noise is its effect on workers' personalities. A study of steel workers has shown that men who work in noisy conditions were more aggressive, distrustful and even paranoic than were men who worked in quieter circumstances.

Let us now consider the legal consequences of sound pollution. Noise as a legal problem in American society has been around for a long time. In the 1800's a group of residents on properties adjourning a blacksmith shop went to court complaining of the noise from the continual operation of large sledge hammers. The court granted an injunction restraining operation of the shop between 8 P.M. and 6 A.M. The following are possible grounds for legal action because of excessive noise:

Violation of municipal zoning ordinances.

Interfering with rights of neighbors.

Subjecting an employee to continuing excessive noise.

Subjecting a person to a single excessive noise.

It is not enough that zoning codes and laws are in existence, people must become involved in their enforcement. Too many of us today are apathetic and willing to accept the cacaphony that surrounds us. On the local level there are statutes and codes that the local enforcement agencies may not be anxious to bring into play. It behooves the private citizen to take a stand against noise.

On the federal level there have been some small strides taken. For example, the Walsh-Healey Act which contains noise pollution restrictions that must be observed by companies doing more than $10,000 worth of business with the government. The law applies to plants, factories, buildings or surroundings or under other working conditions. There is also a federal law that includes noise pollution restrictions on construction sites.

Recently in New York a judge ruled that to constitute a nuisance, a noise must only be "unusual, ill tuned, or deafening and must interfere materially with the comfort of ordinary people."

It would seem that 90% of the sound that surrounds us can be considered a nuisance.

II. PHYSICS OF SOUND

A famous old riddle considers the problem of a large oak tree falling in a forest. If no one was in the forest at the time the tree fell, the question is raised as to whether a sound was produced when the tree crashed into the ground. The answer to this question is based on the definition of sound. According to Webster's New World Dictionary of the American Language, Second College Edition, sound is defined as vibrations in air, water, etc. that stimulate the auditory nerves and produce the sensation of hearing. According to Webster's definition, it is necessary that the auditory nerves be stimulated in order to have sound and, therefore, no sound was produced for the case of the tree falling in the forest.

Scientifically, sound is defined as a rapid, small scale fluctuation of the instantaneous air pressure above and below the local barometric pressure. In a physical sense sound is the vibration of particles in a gas, liquid or solid. Since there are no particles in a vacuum, sound cannot be transmitted in a vacuum. Using the scientific definition, sound was produced as the tree crashed into the ground. This example indicates the importance of knowing the definition of the terms and the assumptions used in discussing a problem.

Noise is defined as those sounds which arouse such negative responses as - unpleasant, discordant, distorting or painful.

Therefore, noise is sound which is unwelcome, unwanted, uninvited, uncomfortable and unhealthy. An alternate technical definition is that noise is a sound which is erratic, intermittent or statistically a random oscillation.

As indicated in the scientific definition of sound, sound is produced by the vibration of particles. In air this vibration results in a variation in pressure as shown in Figure 1. Consider that a tuning fork is producing the pressure variation as shown in the figure. The pressure variations eminating from the tuning fork are called sound waves. Sound waves are longitudinal waves which cause the medium to vibrate parallel to the direction in which the wave is moving. Longitudinal waves are also generated when a pebble is dropped into water.

The loudness of sounds are associated with the amplitude of the pressure wave. As the ear drum receives a wave of increased amplitude, the ear drum is caused to vibrate with increased amplitude. This psychology gives us the feeling that the sound is louder. Scientists and acoustical engineers relate the loudness of a sound wave to a quantity called intensity. The intensity is defined as the power supplied to a unit area of a surface exposed to the sound. The normal units for intensity are watts per square centimeter. For simple motion performed by vibrating particles, the intensity of the sound wave is proportional to the square of the amplitude of the pressure wave.

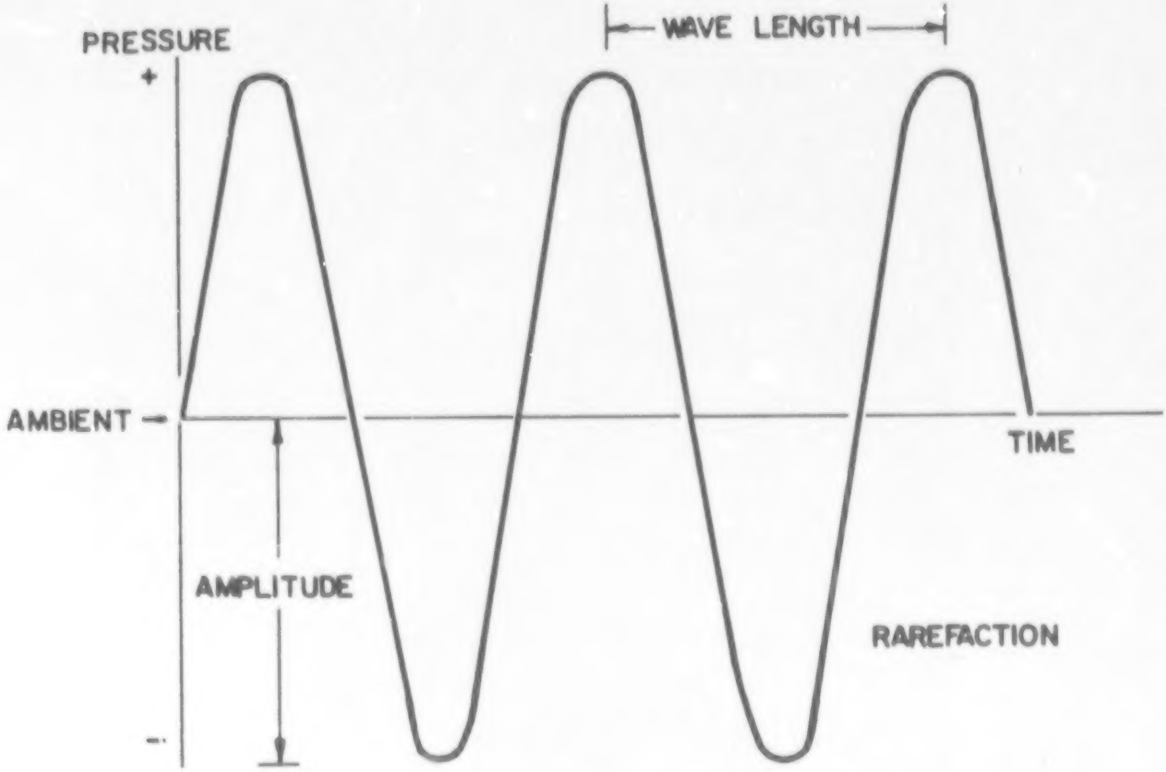
WAVE LENGTH
PRESSURE
+
AMBIENT
TIME
AMPLITUDE
RAREFACTION
-

FIG.1 VARIATION OF PRESSURE WITH TIME AT A POINT

In a sound wave, one compression and one rarefication constitutes a cycle. The number of cycles per second is defined as the frequency of oscillation. The wave length in seconds is the inverse of the frequency of oscillation in cycles per second. The pitch of sound is related to the frequency of oscillation. We say that a sound is high in pitch if its frequency is high, and low in pitch if its frequency is low.

The sound wave moves through an elastic medium at the speed of sound. For air, the speed of sound at room temperature is approximately 1100 ft/sec. and increases at a rate of 2 ft/sec. per degree Centigrade. The speed of sound in various materials is shown in the table below:

TABLE I - SPEED OF SOUND IN MATERIALS

Substance	Speed of Sound
Rubber	127 ft/sec.
Water vapor	1,315 ft/sec.
Lead	4,026 ft/sec.
Alcohol	4,072 ft/sec.
Hydrogen	4,165 ft/sec.
Water	4,794 ft/sec.
Copper	11,480 ft/sec.
Brick	11,980 ft/sec.
Iron	16,410 ft/sec.
Glass	16,410 ft/sec.
Aluminum	16,740 ft/sec.

The fact that speed of sound generally is higher in solid materials than in air was used by the Indians in determining the approach of a man on horseback. By putting his ear to the ground, the Indian heard the sound of the hoof beats long before he saw the approaching horseman.

When a sound falls upon a hard surface, such as a wall or a floor of a room, it is reflected. One result of the reflection of sound is the echo. If an observer in a favorable location makes a sound, in time that sound strikes a solid surface and is reflected back to him. The time required depends on how far away the reflecting surface is. If the reflector is 550 feet away, the sound must travel 550 feet and back, a total of 1100 feet. Since at normal room temperature sound travels 1100 feet per second the echo will be heard about 1 second after sound is produced. In fact, seafaring men used this principle in reckoning distance to obstacles when there was thick fog cover. They would time the echo of their ship's whistle. The principle is still used today, only instead of using sound waves, high-frequency radio waves are used. Since radio waves travel at the speed of light - 186,000 miles per second - it is possible to detect an object 550 feet away in only .00000112 seconds. The device used for detection is called radar. For underwater applications radar is ineffective because of the dissipation of the energy of the radio waves in water. Sonar, which is based on the reflection of sound waves, is used effectively for underwater applications. It is used for the mapping of the ocean floor, submarine navigation, and the location of schools of fish.

III. MEASUREMENT OF SOUND

The loudest sound pressure that a person can hear without experiencing pain is 10 million times the softest sound that is barely discernable under ideal conditions. This ratio of 10,000,000:1 makes the use of a linear scale for sound pressure impractical. In order to deal conveniently with such a large range of numbers, a logarithmic measure defined as the decibel (dB) is used for the measurement of sound level. The decibel is a dimensionless unit for expression of the ratio of two values of sound pressure. When the unit is used to express a sound pressure level, a reference pressure is always implied. The reference level for decibel readings corresponds to the weakest sound level that can be heard by a person with very good hearing in an extremely quiet location. This reference sound pressure level is .0002 micro bars = .0002 dynes/cm^2. The mathematical relationship between sound pressure level and sound pressure is

$$SPL = 20 \log (p/.0002)$$

where SPL is the sound pressure level in dB

p is the root mean square sound pressure in microbars.

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As mentioned in the previous section, the intensity or power of a sound wave is proportional to the square of the amplitude of the pressure wave. Therefore, the sound intensity that is emitted by a source can be expressed as

$$SIL = 10 \log I/10^{-12}$$

where SIL is the sound intensity level in dB

I is the sound intensity in watts

10^{-12} watts corresponds to the weakest audible sound.

Table 2 presents typical sound levels for noises in the outdoor and indoor environments.

TABLE 2 - TYPICAL SOUND LEVELS

Sound Level (dB)	Sound Pressure (microbars)	Sound Power (watts)	Source
10	.0002	10^{-12}	Threshold of hearing
20	.002	10^{-10}	Rustle of leaves, Studio for sound pictures
40	.02	10^{-8}	Bird calls, average residence
60	.2	10^{-6}	Air conditioning unit at 100 ft., Conversational speech
80	2	10^{-4}	Passing truck, Garbage disposal unit
100	20	10^{-2}	Power mower, automatic lathe
120	200	1	Loud automobile horn, oxygen torch.
140	2000	100	Threshold of Pain

Since a logarithmic scale is used for sound level measurements, it should be noted that the following relations exist:

a) A difference of 1 dB is approximately the smallest change in sound level that the average person can detect.

b) If the sound pressure is doubled, the SPL is increased by approximately 6 dB. If the sound pressure is increased ten fold, the SPL is increased 20 dB.

c) If the sound intensity is doubled, the SIL is increased by approximately 3 dB. If the sound intensity is increased ten fold, the SIL is increased by 10.

d) When two sources producing sound levels of 80 dB each are operated simultaneously, the resulting sound level is not 160 dB but only 83 dB. Appendix I presents a method for adding and subtracting sound levels.

Sound level measured in decibels depends upon the strength of the pressure fluctuations around the ambient pressure. It is measured by a sound level meter which consists of a microphone to convert the pressure fluctuations into a corresponding fluctuating electrical voltage, amplifiers, a weighing network that shapes the voltage to account for the response of the ear, and a voltmeter. Since the voltage output from the microphone is dependent upon the sound pressure level, the meter is normally calibrated to read sound level directly in decibels.

The American National Standard for Sound level meters has specified the frequency response characteristics of the weighing networks for sound meters as shown in Figure 2. Responses A, B and C selectively discriminate against low and high frequencies. When making sound level measurements with a sound level meter, it is recommended that readings be taken on all three weighing networks. If the dB reading is the same on all three networks, the sound probably predominates in the frequency range above 600 cycles per second. If the reading on the C network is higher than that on the A and B networks, the sound probably predominates in the frequency range below 600 cycles per second.

Noises that are measured are very rarely pure tones or single frequencies. In fact they are usually a conglomeration of sounds that may range from a low frequency roar to a high frequency squeal. The ear reacts to these sounds in different ways depending not only on the overall levels, but on the composition of the noise as a function of frequency. In order to measure this composition a frequency analysis is performed which will indicate how the sound energy is distributed over the audible range of frequencies. The three methods used are Octave band, Narrow band, and One-third band; essentially they are methods of breaking up the audible spectrum of frequencies into smaller bands and determining the level for each band.

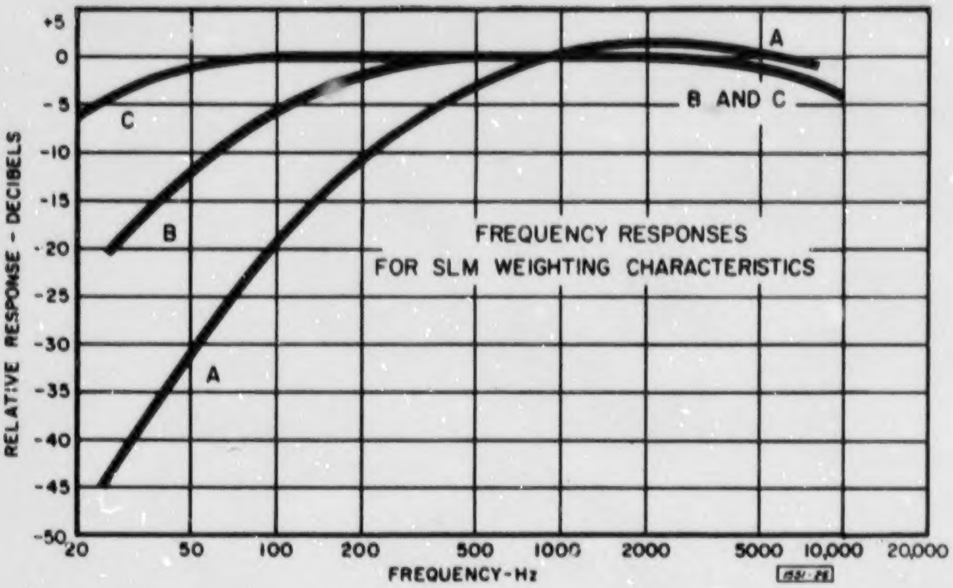


FIGURE 2 FREQUENCY RESPONSE CHARACTERISTICS IN THE AMERICAN NATIONAL STANDARD SPECIFICATION FOR SOUND LEVEL METERS ANSI - S1.4 - 1971.

(Source: Handbook of Noise Measurement, Seventh Edition, 1972, by Arnold P.G. Peterson and Ervin E. Gross, Jr., General Radio Company, Concord, Mass.)

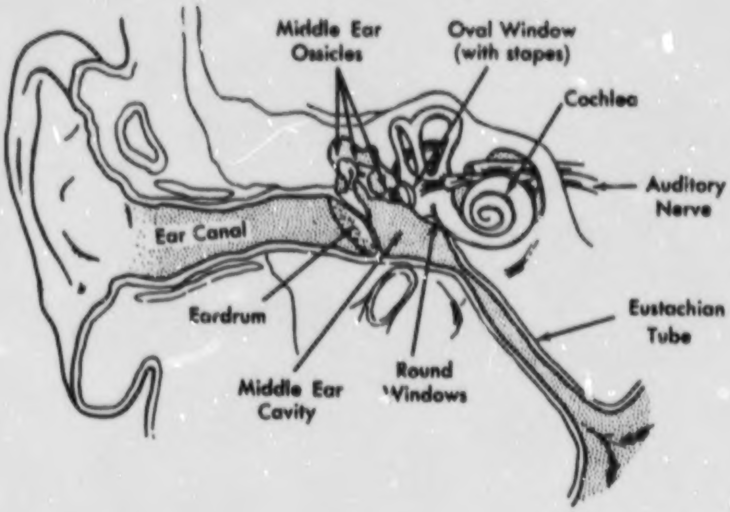
IV. PHYSICS OF THE EAR

Since sound waves are longitudinal, any receiver must include a member which is capable of responding to this type of wave. In the invertebrates, hair-like appendages serve this purpose. In the higher animals, particularly in man, the hearing organ is quite complex enabling man not only to detect sounds of infinitesimal energy, but also their quality.

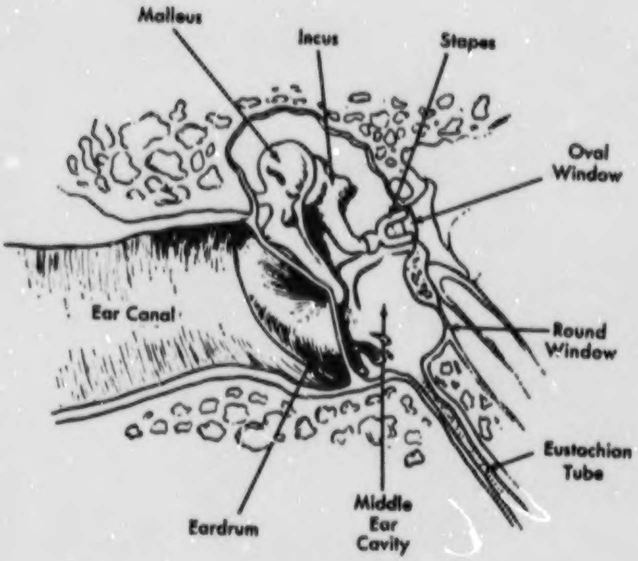
The human ear consists of three main parts as shown in Figure 3: the outer ear, the middle ear and the inner ear. Each plays an important part in hearing.

The outer ear consists of the auricle and the ear canal. The auricle is the fleshy curved part which is attached to the side of the head. Its cuplike shape enables it to collect sound waves and direct them into the ear canal. The purpose of the ear canal is to guide the sound waves into the middle ear.

The function of the middle ear is to transmit the soundwave from the ear canal to the heavy inner ear fluid. The middle ear consists of the ear drum and the auditory ossicles. The ear drum is a thin sheet of tissue which separates the middle ear from the ear canal. When the sound waves reach the ear drum, the ear drum vibrates in response to the sound pressure. The vibrations are transmitted to the inner ear by means of the ossicles, which consists of the three smallest bones in the body. The three bones are the mallus (hammer), the incus (anvil) and the stapes (stirrup). The


Middle Ear Ossicles
Oval Window (with stapes)
Cochlea
Auditory Nerve
Ear Canal
Eardrum
Eustachian Tube
Round Windows
Middle Ear Cavity

a) Over-all Cutaway View


Malleus
Incus
Stapes
Oval Window
Ear Canal
Round Window
Eustachian Tube
Eardrum
Middle Ear Cavity

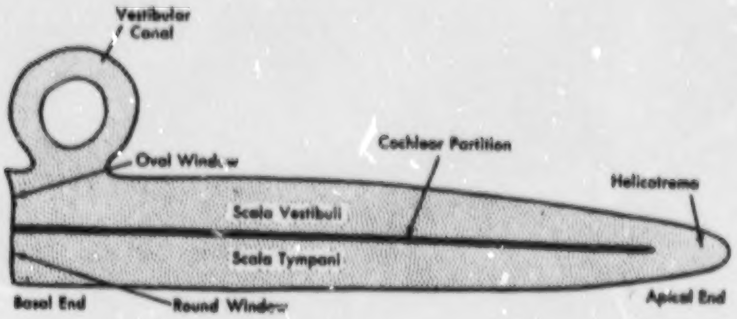
b) Cross-Sectional View of the Middle Ear

FIGURE 3 THE HUMAN EAR

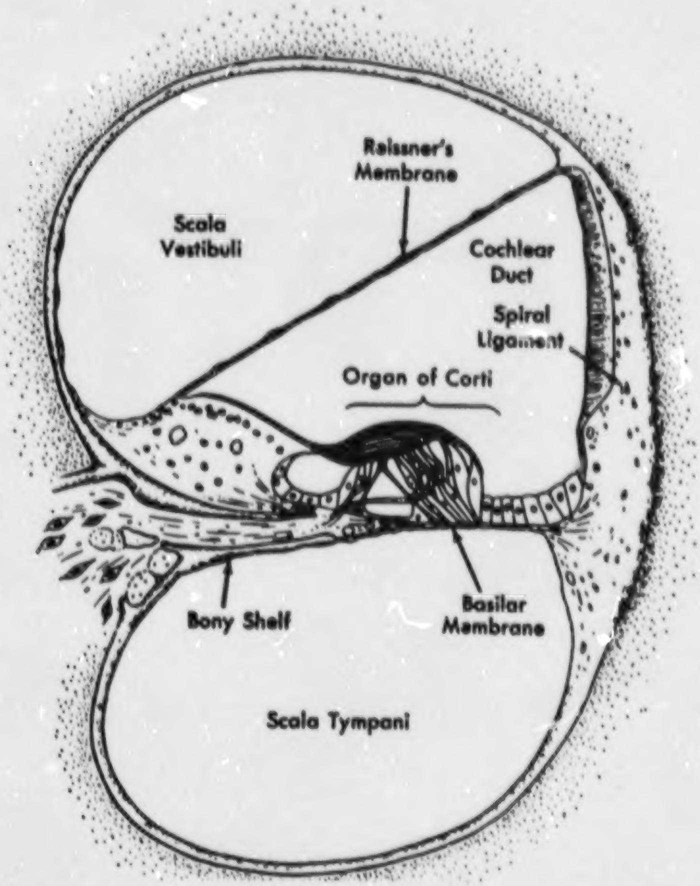
(Source: Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970)

bones are similar in shape to the objects for which they are named. The malius is attached to the ear drum and the stapes is attached to the oval window of the inner ear. The bones in the middle ear behave as a miniature lever system and increases the magnitude of the force exerted on the ear drum at the expense of the magnitude of the motion.

The inner ear contains many intricate chambers and passageways. Three semi-circular canals, which give us our sense of balance, are located in the inner ear. Located directly behind the oval window, which separates the middle and inner ear, is the conchlea. The conchlea is a snale-like organ which is filled with fluid. The conchlea is divided into two sections by the basilar membrane. (Figure 4). The Organ of Corti is located on the basilar membrane. (Figure 5). It is a transducer like mechanism which is responsible for translating acoustic hydraulic pressure impulses into neutral impulses - a common language between the brain and its many sensory imputs. This juncture is effected at the hair cells as the hairs are bent in contact with the tectorial membrane. In general terms, certain areas along the basilar membrane of the conchlea are charged with certain portions of the audible frequency range - lower frequencies assigned near the cochlea apex or widest part of the membrane, and higher frequencies to the basal or narrower part of the membrane. There are three parallel rows of outer hair cells and one row of inner hair cells. The former are far more liable


Vestibular Canal
Oval Window
Cochlear Partition
Helicotrema
Scala Vestibuli
Scala Tympani
Basal End
Round Window
Apical End

a) Longitudinal Section of the Unrolled Cochlea


Reissner's Membrane
Scala Vestibuli
Cochlear Duct
Spiral Ligament
Organ of Corti
Bony Shelf
Basilar Membrane
Scala Tympani

b) Cross-Section Through Unrolled Cochlea

FIGURE 4 THE COCHLEA

(Source: Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970)

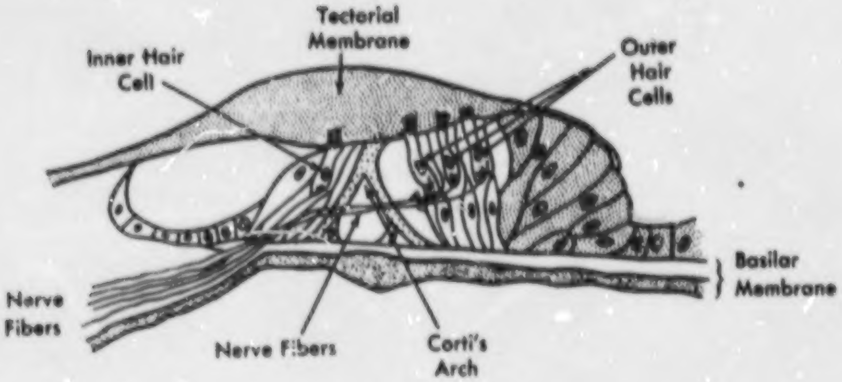

Tectorial Membrane
Inner Hair Cell
Outer Hair Cells
Basilar Membrane
Nerve Fibers
Nerve Fibers
Corti's Arch

FIGURE 5 DETAIL OF THE ORGAN OF CORTI

(Source: Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970)

to noise - induced physiological damage than are the latter. The vibration of the hair cells stimulates nerves attached to them. These nerves send messages through the auditory nerve to the brain.

The useable range of auditory sensitivity extends non-linearly from frequencies of 16 cycles per second to 20,000 cycles per second in a young normal hearing adult. Figure 6 illustrates the auditory threshold for a typical group of Americans. The curves are labeled by the percent of the group that could hear tones below the indicated level.

V. AUDIOMETRY

The instrument used for measuring the acuity of a person's hearing is called an audiometer. Since audiometric procedures are used mainly for the detection and investigation of impaired hearing, the results of the measurement are usually expressed in terms of "hearing loss " relative to the acuity of an average normal ear. In general the audiometer is comprised of three basic components: (1) a sound generator which produces the signal the person hears, (2) a means for controlling the sound level of the signal and (3) a means for applying the sound to the listener's ear.

In the past such things as bells, tuning forks, coin clicks, the whispered voice, and many other devices were used to test a person's hearing acuity. Most of these early devices suffered from

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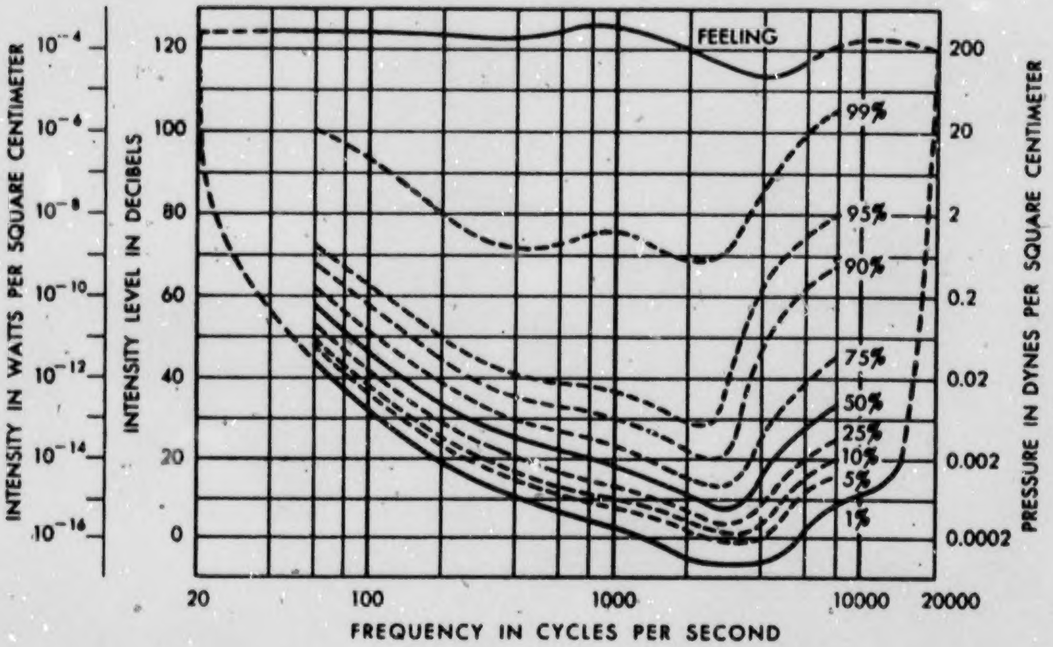

FIGURE 6 ABSOLUTE AUDITORY THRESHOLD FOR A TYPICAL GROUP OF AMERICANS

(Source: Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970)

difficulties in controlling the level and the frequency of the sound signals. Standardization of the signals with any reasonable accuracy was practically impossible in most cases. With the advent of the vacuum tube, transistor and the simultaneous advances in design of electrical and electronic circuits, it has become possible to build compact highly stable audiometers. By means of standard procedures for acoustical and electrical measurements all modern audiometers may be calibrated to give essentially identical results within practical tolerances. Therefore, results of audiometric tests made at various clinics or laboratories may be safely compared.

Of the many types of sound signals which might be used for audiometric work, there are two which are used almost exclusively: (1) pure tones, and (2) speech. Although both types are available in commercial form the pure tone type is the most widely used.

The procedure for determining a person's hearing loss is the same with either instrument. Beginning with the sound signal at a level that is audible to the patient, the operator gradually reduces the signal level by adjusting a calibrated dial until the patient indicates that the tone is no longer audible. The sound level is then brought up from a definitely inaudible level until the listener signals that the tone is again heard, again the dial reading is noted. Several such pairs of readings are taken and the average is considered to represent the hearing loss of that person for the particular frequency of sound employed. The hearing loss is determined for a number of frequencies the results are plotted on a graph of hearing loss versus frequency which is called an audiogram.

The pure tone audiometer comprises three units: (1) an electronic generator for generating electric currents of various frequencies, (2) an amplifier with a volume control calibrated in 5 db steps, (3) an earphone for applying the sound to the listener's ear. This type of instrument may employ other variations such as recordings to supply the sound signal or a loud speaker to apply the sound to the listener's two ears simultaneously. The instrument has three dials. The first dial is usually the coarse frequency selector, the second a fine frequency control. The third dial is the sound pressure level control calibrated in 5 db steps of hearing loss. There are two types of earphones that may be used: (1) air conduction type, from which the sound is conducted by air down the auditory canal to the ear drum, or (2) bone-conduction type, which is pressed against a bony portion of the head (usually the mastoid, back of the ear) from which the sound travels through the skull to the inner ear. Both types are used in diagnosis since they may not yield the same results on a given ear. For example, if the inner ear is normal but a mechanical obstruction exists in the middle or outer ear, the hearing loss for air-conducted sound may be much greater than for bone conducted sound.

There are two varieties of pure tone audiometers in common use today. - (1) the fixed frequency or descrete frequency type and (2) the sweep-frequency type. The descrete-frequency audiometer generates sounds of only a certain limited number of frequencies. For example, such tones as 128, 256, 512, 1024, 2048, 4096, and 8192 cycles per second. These are the most frequently used frequencies for clinical audiometry. The sweep-frequency type of audiometer is designed to give tones of any frequency between a lower and an upper limit by merely turning the dial. The operator may "sweep" through the entire frequency range.

VI. MEDICAL EFFECTS OF NOISE

The major effects of noise may be tentatively classified under three basic headings as follows:

I. Physiological

A - Direct

1 - Permanent loss of hearing or what is known as PTS (Noise induced Permanent Threshold Shift).

2 - Temporary loss of hearing or TTS. (Noise-induced Temporary Threshold Shift).

B - Indirect

1 - Fatigue, caused by a lost or noise disturbed sleep.

2 - Autonomic nervous system effects vasodilation.

II. Physical

Interference with spoken communication or SIL (Speech Interference Level).

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III. Psychological

- A - Direct
  - 1 - Annoyance
- B - Indirect
  - 1 - Tension, inefficiency and subsequent loss of work productivity.

If we were to consider sequentially the direct effects of noise indicated above we would notice that we descent from

Permanent Threshold Shift
to
Temporary Threshold Shift
to
Speech Interfernce
to
Annoyance

(1) The required acoustic noise energy decreases with each lower order effect. For example - The noise from a neighbor's air conditioner may not be of sufficient level to interfere with speech communication, yet depending on the hour of the day it may well be classified as Annoyance.

(2) Noises which at their source originate with intensities providing higher order effects such as permanent threshold shift will generally result in lower order effects at

greater distances since the intensity will be proportionately lower. For example - The noise produced by an unmuffled Jack hammer is of sufficient magnitude to permanently impair the operator's hearing. At 50 to 100 feet distance, average conversation is impossible, while one block away to an individual attempting to concentrate on a difficult task it may prove quite annoying.

(3) As the order of effects decreases, the effects become more subtle or evasive and more difficult to document. For example - The permanent hearing loss sustained by the Jack hammer operation cited above may easily be assessed through audiometry tests. The temporary loss of hearing suffered by the people in the immediate vicinity will slip away with rest, time and the removal of the obnoxious sound. Finally how does one measure or scale levels of noise produced annoyance?

Numerous studies have been undertaken to assess those critical noise levels which may permanently damage hearing. The results are in fair agreement. The sound levels of concern lie between 85 db and 95 db for octave bands* within the frequency region

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* Octave band is a band of frequencies between any two arbitrarily chosen frequencies having a ratio of 2:1. That is the higher frequency is twice the lower. This is a method of specifying the frequency composition of noise, by dividing the frequency spectrum into various octave bands.

300 cps to 4800 cps.

The extent of effects on hearing depends upon duration and frequency of exposure to the noise as well as certain elusive qualities which make some ears more susceptible than others. It is unlikely that levels below this range will result in impaired hearing. The effect of noise on people is cumulative, it produces an "acoustic fatigue". Repeated moderate noise builds up to inflict the same damage as a single loud noise. Even more important, repeated noise is the only type (short of a shattering explosion) that produces permanent hearing loss.

Some of the hearing loss from acoustic fatigue is recovered when the noise is removed, but the permanent damage cannot be determined until the injured person has been away from the injurious noise for several months. In the case of a loud explosion or other intense sound, hearing ability may not stabilize for many months after.

The hearing loss suffered by individuals from years of exposures to noise usually differs in various portions of the hearing range. Figure 7 presents the results of a study of people who regularly worked in a 90 dB noise environment. The results indicate that little hearing loss occurred in the 1000 cycles per second range until after some 30 years of exposure. However, a 50 dB loss occurred in the 4000 cycles per second range after an exposure of only 16 years.

Figure 8 shows the permissible daily duration of exposure to

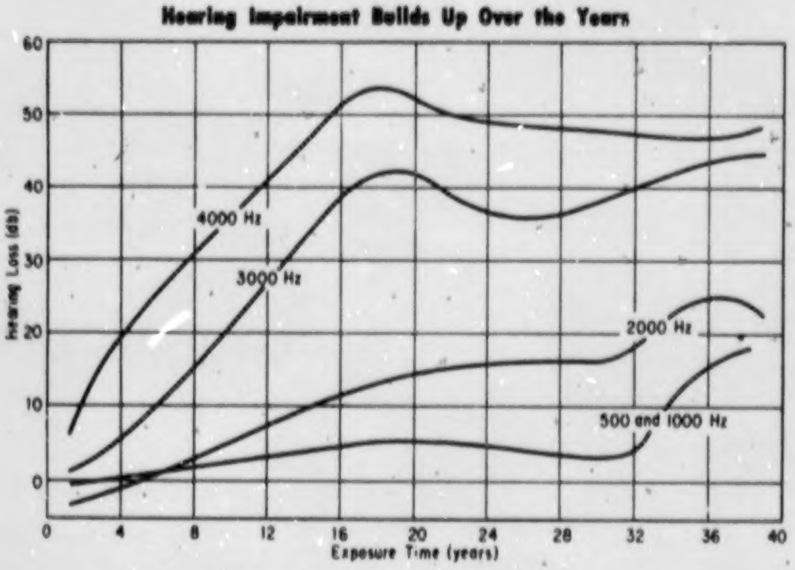

FIGURE 7 HEARING LOSS FOR INDIVIDUALS WORKING IN A 90 dB NOISE ENVIRONMENT

(Source: The Anatomy of Noise by Leo Beranek and Layman Miller. Machine Design, September 14, 1967)

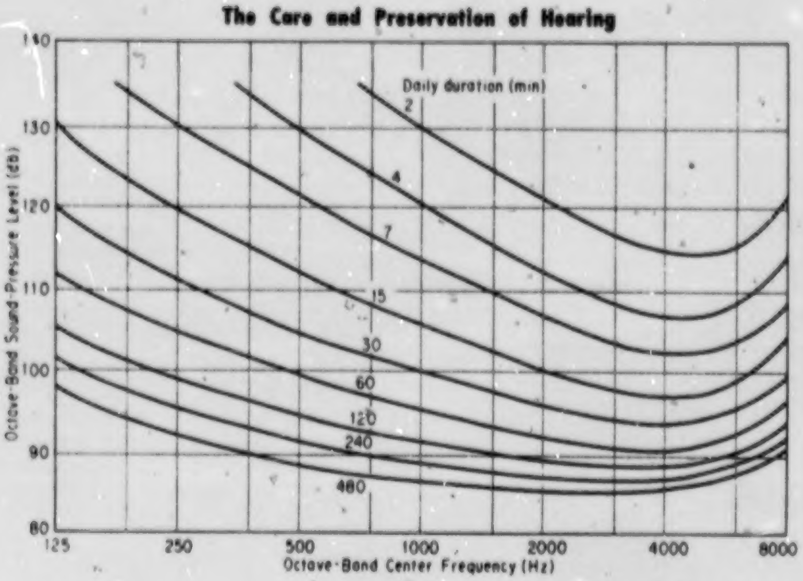

FIGURE 8 PERMISSIBLE DAILY DURATION OF EXPOSURE TO NOISE TO PREVENT SERIOUS HEARING LOSS IN 10 YEARS

(Source: The Anatomy of Noise by Leo Beranek and Layman Miller. Machine Design, September 14, 1967) noise to prevent serious hearing loss in 10 years. On the basis of available data, standards set under the Walsh Healy Public Contracts Act now sets 8 hours as the maximum time a worker can be exposed to noise levels of 90 dB.

Aside from hearing loss, noise may cause cardiovascular, glandular, respiratory, and neurologic changes, all of which are suggestive of a general stress reaction. These physiologic changes are produced typically by intense sounds of sudden onset, but also can occur under sustained high level, or even moderately strong, noise conditions. Whether such reactions have pathologic consequences is not really known and may be unlikely in view of the body's capacity to adapt to prolonged or recurring forms of sound stimulation including those of fairly high level. However, there are growing indications, mainly in the foreign scientific literature, that routine exposures to intense industrial noise may lead to chronic physiologic disturbances. A German study, for example, has shown a high incidence of abnormal heart rhythms in steel workers exposed to high noise level in their workplaces. Neurological examinations of Italian weavers, also exposed daily to intense noise, have shown their reflexes to be hyperactive, and, in a few cases, electroencephalography has revealed a pattern of desynchronization as seen in personality disorders. A study reported in the Russian literature shows that workers in noisy ball-bearing and steel plants have a high incidence of cardiovascular irregularities such as bradycardia (i.e., slower heart beat). Subjective complaints of extreme fatigue, irritability, insomnia, impaired tactile function and sexual impotence also have been made by workers repeatedly exposed to high level industrial noise. All of these disturbances appear marginal in nature and may be difficult to relate causally to noise. Other factors in the work situation or in the specific group under study might have been responsible for the observed problems. In any case, corroboration of these findings is needed and a broad-scale survey of non-auditory disorders among workers in noisy industries might prove illuminating.

Noisy conditions in work areas can interfere with speech reception and impair worker performance on jobs requiring reliable voice communication. Noise effects on performance, not dependent on voice communication, are uncertain. Available information suggests that workers devoting constant attention to detail (e.g., quality inspection, console monitoring) may be most prone to distraction. Noise may mask auditory warning signals and thereby cause accidents or generate reactions of annoyance and general fatigue. With reference to the latter, it has been stated that man must work harder under noisy conditions than in quiet to attain the same job output. The fact that much of these data are conjectural demonstrates that additional research is needed to determine their validity.

Data coupling industrial noise conditions with measures of accident rate, absenteeism and employee turn-over are not available. Noise may be implicated in such occupational problems but casual relationships might be difficult to demonstrate. It should be stressed that reducing industrial noise conditions to levels non-hazardous to hearing will minimize but not eliminate the performance-behavior problems just described. Clearly, there is need for additional basic research to determine the full spectrum of the affects of human exposure to a noisy environment.

7. LEGAL ASPECTS OF NOISE[*]

Noise, as a legal problem in the United States, has some very deep roots. Historically there were always remedies against such nuisances as "smoke, noxious vapors and noisome smells". These categories seemed enough until the industrial revolution brought about the nuisance of "noise" which might not be connected with smoke, vapors or smells. During colonial times in the United States noise as a "nuisance" was a matter of law in England. In the case of Jones vs. Powell of 1628, the court passed the following ruling:

"A tannery is necessary, for all wear shoes, and yet it will be pulled down if it is erected as a nuisance to others".

This type of "nuisance law" was adopted in the United States as "common law" until their codification into legislation in the act of 1865. In the 1800's a group of residents on properties adjourning a blacksmith shop went to court complaining of the noise from the continual operation of large sledge hammers. The court granted an injunction restraining the operation of the shop between the hours of 8 p.m. and 6 a.m.

Although the earliest cases in New York related to smells and noxious odors, it must be understood that the rule with regard to abating smells was no different from that for abating noise. Therefore, the following quotations are quite relevant:

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[*] A major portion of the material presented in this section is reproduced from the report "Toward a Quieter City", Mayor's Task Force on Noise Control, New York City, 1970.

"To constitute a nuisance it is not necessary that a smell should be unwholesome, but sufficient if it renders enjoyment of life and property uncomfortable - it is sufficient if it produces that which is offensive to the senses and impairs enjoyment of life and property".

"It is not sufficient that it is merely disagreeable; it must be an annoyance calculated to interrupt the reasonable enjoyment of life and property".

The original legislation in New York was Sec. 385 and 386 of the Penal Code of 1881. Later it was amended by Chapter 367, Sec. 1 of the Laws of 1901. After that it was incorporated as Sec. 1530 of the Penal Code of 1909. Finally it found itself as Sec. 240.45 of the Penal Code of 1965 which is the present Code. The original misdemeanor penalized one who "annoys, injures or endangers the comfort, repose, health or safety of any considerable number of persons". The current section penalizes one "who by his conduct either unlawful in itself or unreasonable under all the circumstances creates or maintains a condition which endangers the safety or health of a considerable number of persons".

Supplementing the general law for the abatement of nuisances, New York State has enacted laws against particular noise nuisances in the motor vehicle field.

(a) Against improper motor cycle mufflers - Motor Vehicle Law Sec. 381-1

(b) Against gongs or sirens other than authorized emergency vehicles - Motor Vehicle Law Sec. 375-26

(c) Against inadequate mufflers for motor vehicles - Motor Vehicle Law Sec. 375-31

(d) Against excessive or unusual noise of motor vehicles and defining the same as a sound level above eighty-eight decibels on the "A" scale at less than 35 mph and 50 ft. from the center of the traffic lane - Motor Vehicle Law Sec. 386

(e) Against individuals on the principal of preventing disorderly conduct, for any unreasonable noise - Penal Law Sec. 240.20

The City of New York has, among other things, taken the following action:

(a) Against unnecessary noise generally now Administrative Code Chap. 18 under the Police Dept. Title "A" Sec. 435-5 which prohibits "any unreasonably loud disturbing and unnecessary noise....of such character, intensity and duration as to be detrimental to the life or health of any individual (and in particular):

(1) Horns and signal devices on automobiles and other vehicles while stationary, except as a danger signal, and while in motion only as a danger signal.

(2) Operation of any radio, phonograph, etc. in such a manner or with such volume, particularly between 11:00 p.m. and 7:00 a.m., so as to annoy or disturb the quiet, comfort or repose of persons in any dwelling, hotel or other type of residence".

(3) The keeping of any animal or bird causing frequent or long continued noise which shall "disturb the comfort and repose of any person in the vicinity".

(4) Use of vehicle so out of repair, so loaded or in such a manner as to create loud and unnecessary grating, grinding, rattling or other noise.

(5) Unnecessary blowing of any steam whistle.

(6) Use of a stationary internal combustion engine without a muffler "which will effectively prevent loud or excessive noise therefrom".

(7) Building construction or demolition, etc. except between 7:00 a.m. and 6:00 p.m. on week days, except in case of urgent necessity and then only by permit.

(8) Excessive noise adjacent to schools, hospitals, etc.

(9) Loud and excessive noise in connection with loading or unloading vehicles, etc.

(10) Shouting or crying of peddlers, etc.

(11) Use of loud speakers, etc. for attracting attention to a display of merchandise, etc.

(b) Against sound amplification devices on the street or abutting the street, Sec. 435-6 of the Administrative Code under a legislative declaration that such amplification noise is detrimental to the health, welfare and safety of the inhabitants of the City .... (and by diverting the attention of pedestrians and vehicle operators in the streets is) increasing traffic hazard and causing injury to life and limb .... disturbs the public peace and comfort and the peaceful enjoyment by the people of their rights to use the public streets, parks .... and disturbs the peace, quiet and comfort of the neighboring inhabitants". All commercial use of such amplification is prohibited and any use other than commercial requires a permit.

(c) Supplementing the General Code, the City also includes a traffic regulation Sec. 151 against sounding a horn except to warn against danger.

(d) The Department of Markets of the City has also a rule and regulation preventing bells, gongs or noise from itinerant peddlers and preventing any hawking of wares except between 9:00 a.m. and 9:00 p.m. and permitting sound devices that do not increase the sound pressure level at a distance of 10 feet by more than 4 decibels.

(e) By the Health Code of the City Sec. 135.19 the department may take measures to eliminate or reduce excessive or unduly annoying noises and may require noise reduction and abatement devices, or other means of reducing noisome conditions or conditions dangerous to health.

(f) The City also controls, by licenses, places of public assembly and makes rules in the license department for the hours in which these places may be open and limits them particularly in residential (zones) districts.

The City of New York has also established an Environmental Protection Administration with the powers and duties to regulate the emission of all harmful or objectionable noises or other vibrations and to make rules through the action of an Environmental Control Board.

On the subject of aviation noise the City and State must work with the Federal Aviation Administration since they are the controlling agency. Unfortuantely, there has not been any strong federal legislation in the area so that the problem facing residents adjacent to airports be solved. Although the City has appropriate noise legislation, it has been quite lax in its enforcement of these laws.

On the federal level, Congress passed the Walsh-Healey Public Contracts Act which requires that any contracts entered into by any agency of the United States for the manufacture or furnishing of materials, supplies, articles and equipment in any amount exceeding $10,000 must contain a stipulation that "no part of such contract will be performed nor will any of the materials, supplies, articles or equipment be manufactured or fabricated in any plants, factories, buildings or surroundings or under working conditions which are unsanitary or hazardous or dangerous to the health and safety of employees engaged in the performance of said contract."

It has been the hue and cry that what is needed is stiffer legislation on the part of every level of government so that the problem of noise can be reduced if not eliminated. Unfortunately, this is not the complete solution. It is more important that extensive educating campaigns be conducted so that both law makers and business leaders are made aware of the many intricacies of the problem of noise pollution. Other pressures beside legislation can be brought to bear. For example, the respective governmental agencies can use their buying power to effect some degree of control. The power of licensing can also go a long way in exerting pressure on industry to modify its methods so that the existing noisy environment is made more liveable.

a) Source of Noise and Their Control

Practically all noises in a large city can be divided into five categories.

A. Transportation

B. Industrial

C. Construction

D. Heating, Venilating and Air Conditioning equipment

E. Man in his day-to-day activity (this includes commerce and business activity in the streets, the police and fire departments and the collection of refuse).

A. Transportation Noise

1. Rail transportation noise includes the actual clanking and rattling of train operation on the tracks, the squeal of wheels going around curves, the whistles and the release of pressure on the air-brakes after the train has stopped. Trains are particularly noisy on elevated structures which are more effective sound radiators than the train itself or the concrete or earth track-beds at ground level or below ground.

2. Trucks generate noise through a number of sources. In both diesel and gasoline operated trucks, exhaust noise can be a serious source of noise. In diesel trucks the engine noise is often effectively radiated from the engine itself, and this may be exposed to the public's ear by a light louvred, sheetmetal hood. Truck transmissions radiate a considerable amount of gear noise as do the differential gear enclosures. A chain drive radiates noise directly. It has a readily identified whine and is

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a frequent source of complaint. This type of drive is frequently used on earth-moving trucks. Other sources of noise from trucks include: chassis noise, springs, brakes, air compressors, sheetmetal parts, chains and loose pins (which cause "key jangle noise") and tire whine. This last noise is not usually heard in center city areas but is heard adjacent to highways and in perimeter residential areas where the background noise levels are much quieter than center city and truck speeds exceeding 35 mph. Current New York City noise limits exclude truck speeds above 35 mph because truck tire manufacturers continue to mold tire treads which have vacuum-cup type noise sources either originally or as the tire wears. Until the rubber manufacturers eliminate this characteristic from the tread design, truck users are likely to resist any reduction in truck noise limits.

3. Automobiles generate considerably less noise in normal operation than do trucks, but they can, when operated at high speeds on the city's parkways, be unusually unpleasant noise generators. The noises at high speeds include tire squeal, tire tread noise, rattles, engine noise and exhaust. At low speeds automobiles are noted for their engine noise and horn noise. The use of "cutouts" on exhaust systems is illegal and is not as common now as in

earlier years of the automobile. Some use of resonant "hollywood" muffler systems causes unpleasantly loud exhaust noise during starting sequences but they appear to be of limited popularity.

4. Aircraft noise has received such a large share of attention in recent times, that it is obviously a serious noise problem. Aircraft noise affects different parts of the city in different ways. To those who live near airports or on the runway centerline extensions, the sounds of piston and jet engine aircraft landing and taking off interfere with normal human activities including conversation, telephone use and sleep, and are responsible for the interruption of the auditory component of entertainment equipment (e.g., radio, television, outdoor motion pictures). Aircraft noise heard so closely also arouses fear and apprehension. To those who do not live quite so close to the airport boundaries, the noise from aircraft flying overhead and to one side or the other can be a source of distraction, can interfere with the audition of speech and music even though it might not interrupt speech, and can be related to loss of sleep. Sources of noise in aircraft are basically the engine and its intake and exhaust systems. For those who live near airports within the city,the operation of ground

equipment may at times be a source of noise annoyance, but this is usually of much less severity than the actual aircraft operation itself. A particularly noisome aircraft operation is caused by passenger helicopter flights over the city. Helicopters are noisy and the twin rotor Boeing-Vertol has an unusually strong pulsation caused by blades on one rotor cutting the wakes of the blades on the other rotor; this copter also causes vibrations. For those close to the airport, the jet engines used on the helicopters could be sources of annoyance even without the blade-generated noise.

B. Industrial Noise

1. Out-of-doors process operations of industrial plants are not, in general, quiet. Sources include: air intake and discharge ducts or openings from fans and compressors or valves, engine intakes and engine and turbine exhausts, pumps, and pump and engine radiation and steam discharge noise.
2. A fully enclosed industrial plant can generate noise which often reaches residential and commercial neighbors. The sources include many of the same items as the out-of-doors process industries. The intakes and discharges for fans and compressors penetrate the walls of industrial buildings.

Often ducts and piping are run outside the building, frequently over the roof, where they radiate the noises generated elsewhere in the plant. Many plants conduct operations that require the windows to be open all year long. These open windows vitiate any noise control potential of the building walls and roof. Also, annoying noise may leave the building through the openings for fans and blowers which in themselves may not be sufficiently noisy to cause complaints. Typical noise sources in this category include punch presses, machine tools, forging equipment and printing presses.

3. Another industrial noise source which is also interrelated with transportation is plant automobile traffic during night and early morning hours. Shift employees leaving and arriving at other than daylight hours have been a source of complaint in a number of peripheral areas of the city.

C. Construction Noise

1. Diesel engine operated equipment is by far the major noise generator at construction sites. These engines may be used to drive generators, compressors, trucks, shovels, bulldozers, frontloaders, scrapers, power shovels and rock drills.

2. Electric motor operated equipment at construction sites can also be unpleasant noise generators. They have a noise output which may be described as a whining or groaning sound.

3. Air compressors and suction pumps are both loud , unpleasant noise sources at construction sites. The air compressors generate noise from the intake and discharge lines which radiate noise and from the casing which, like the diesel engine, radiates noise directly from the cylinder walls of the machine. The pumps make a number of sounds, some of which are casing-radiated and other of which are pipe or enclosure radiated.

4. Blasting is used at some construction sites within the City and is, in general, only done during the day. The noise from the blasting can be minimized and, in general, is not frequent. However, it is disturbing and causes serious complaints.

5. Pile driving (includes hammer driven caissons) is one of the most persistent and unpleasant noises around any construction site. The noises involved in pile driving include the actual hammer blow on the pile as well as the hammer rebound. However, the noise made by the engine, often a steam unit, can also be equally objectionable.

6. Riveting and electrical or pneumatic nut drivers are also common construction site noise sources. The sound of the riveting hammer has, for many years, been synonymous with building construction. The listener cannot tell the difference between the riveting hammer and the electric or pneumatic nutsetter in many cases.

7. Materials-handling equipment at the construction sites is often a major noise nuisance. The noise includes both demolition and construction work in which rough handling of materials and scrap or the use of scrap materials chutes results in unpleasant noise. Also, elevators and cement mixers have been labelled as noise sources in construction.

8. Special equipment that does not appear on every construction job includes on-site electrical generators and rock drills.

9. Interior finishing and residential construction of wood frame design involves the use of hammers, power saws and electric drills. In the context of the residential community, these can be sources of annoying noise.

D. Heating, Ventilating and Air Conditioning Noise

1. The most common center city noise source in the air-conditioning category is the modern high efficiency

cooling tower. The cooling tower contains two noise sources, fans and water spray. The fans are often of very large size being operated by motors ranging in size from 1 to 100 horsepower. The water spray noise may be particularly annoying in installations near residential areas where even with the fan off the spray noise is objectionable.

2. The increasing use of window or through-the-wall packaged air conditioning units leads to the generation of noise outside the apartment or office which is being cooled. This can create unpleasantly loud noise levels from the compressor and fan sources within or really outside the neighboring air conditioning unit. Another noise which grows with age of the unit is the rattling of loose metal parts and loose window frames.

3. The intakes and discharges for major air conditioning systems for apartments, hotels, offices and various commercial buildings (including theatres, restaurants, and stores) can be just as annoying as their industrial counterparts. For the same size and volume of air they generate the same amount of noise. Also cooling towers, roof mounted compressors and air-cooled condensers can be noise sources in similar situations.

4. Induced and forced draft fans for residential and commercial heating plants are effective noise generators. In some situations they generate noise which only disturbs the tenants. In others they are major community noise sources.
5. A particularly unpleasant noise is generated by high pressure oil burner systems. This is a combination of high speed blower whine and drive motor noise which includes a low pitched hum and in many cases, a distinctive motor whine in part due to cooling techniques used in motors and in part due to basic classical motor design features (slots and bars).
6. Combustion noise is also a problem with oil and occasionally with gas fired boilers. The situation is usually compounded by having the furnace air intake through louvres, an open door or open window. Often the design openings are inadequate and additional windows or doors are left open.
7. Pump noise associated with hot water circulators, chilled water systems, and domestic hot water supply can be effective noise generators. They usually operate as efficient vibration generators, and the piping conveys the vibrations to walls or floors which radiate the noise into the surrounding air.

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8. Window and attic residential ventilating fans, especially of large size, can be a source of annoying noise. This noise can be magnified by certain types of installation which causes the window or attic itself to vibrate and to radiate the sound.

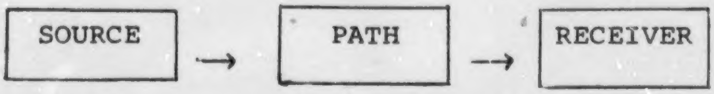
E. Man - Environment Interaction Noise

1. Many noise sources in this class are involved with man in his leisure activities and include such sources as transistor radios, high fidelity stereo and television sets, radio, musical instruments, and home workshop or home improvement tools.
2. Outdoor activites of residential areas include the use of power mowers, power hedge trimmers, and power operated chain saws. Also in this class are the home auto repair man with the noise of the work itself and later the noise of the engine runup.
3. People talking, whether in the street or in neighborhood yards or buildings, can often be a source of annoyance to a neighbor. So can arguments and parties of happy but noisy people.
4. Ice cream trucks, delivery trucks, ambulances, police and fire vehicles with and without sirens.

5. Refuse collection, both public and private, is generally noisy and disturbing. Usual noise sources are the handling of trash cans, engine exhaust noise and truck operated loaders and compactors.
6. Although not usually classified as noise sources, street meetings, religious meetings, outdoor concerts, and church bells have on occasion been listed as sources of complaint with the City.
7. Children at play, whether in a school yard, playground, on the street, or in a neighbor's yard, are often noisy and to some a source of annoyance.
8. Barking dogs also arouse complaints.
9. Sound trucks used for political rallys, for attracting attention to public service activites, and those associated with traveling street amusement devices for children are also sources of annoyance in the City.

b) Control of Noise in the City

The application of any basic modern scientific approach to the current noise control problems in the City or anywhere else is through analysis. Using this approach results in establishment of a three element system:



The three elements, source, path and receiver, can be described in great detail and may have many variations, but it is interesting to examine each in the broadest terms before attempting to establish or evaluate detailed noise control methods.

The receiver of noise is, in our system, man and also animals. Except for those who are hard of hearing, there is little one can do to the receiver of noise to reduce the level or audibility of the noise. It is true that some citizens wear ear plugs or earmuffs, but their use cannot be mandatory nor can it be considered desirable. This rules out one major area of approacch to the noise control problem. Again, continuing back towards the noise source we come to the noise transmission path. Basically, this consists of the air around us and in some cases the earth and building we live and work in. When it is transmitted by the air, it is called air-borne sound. When it is transmitted along pipes and through the building structure, it is considered to be structure-borne sound. All other detailed approaches are variations of these two basic approaches. First we may place a barrier between the source and receiver; this barrier may be a wall or an enclosure for the source or the receiver. When the size and nature of such a barrier bears an appropriate relationship to the source noise levels and the desired receiver environment, adequate noise control results. In the structure-borne case, the approach is to break the solid transmission path by means of actual structural

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breaks, by means of special materials usually sold as vibration isolators, and through redesign of the system which eliminates the structure-borne path. Included in the barrier isolation is the increase of distance between the source and the receiver. It takes a rather great distance to achieve quiet from many sources, but in planning stages,it might be logical to consider the relationship of various new noise-making sources in relation to the rest of the community. Does a new sewer tunnel have to have the air compressor "farm" located right in the middle of a residential area? Just asking the question dictates the answer.

The source, the third element in our noise control analysis, is, in the City situation, the one that most often receives the least attention until impending legal action against the owner or the enforcement of existing statutes forces the owner to examine the possibilities. Much too often it turns out that the noise source is readily amenable to noise control by simple and not too expensive techniques using readily available materials. There is, of course, one quick non-technical approach to technical noise control. That is to make operation of the device without the noise control required by the City illegal, or to put it another way, appropriate statutes could be enacted to require that every source of the specified class be required to have a noise control device also specified in detail by the statute.

It is clear that much of the technical knowledge required to quiet many of the City's most flagrant noisemakers is available, and has been available for some time, but that its application will not be effected until it becomes mandatory.

c) Noise Control Techniques

1. There are several elements in the control of railroad noise sources.

   a) The most important noise control measure is good maintenance. The rattling noises that accompany high-speed operation are not only objectionable, they are unnecessary. The tightening of brake gear and the appropriate adjustment of buffer and striker plates and of the draft gear will reduce noise considerably. Also, matters of wear must be evaluated not only on the basis of maximum mechanical life, but must be examined from the point of view of usable life to the point of excessive noise generation.

   b) One of the most noxious noises produced by trains is the release of the air brake pressure after the train has come to a stop. On grade level and elevated structures such noises which are disturbing to people nearby, especially at night, are also needless. They can readily be muffled by small pressure reduction or expansion type mufflers. These mufflers in no way affect operation of the brakes or the air compressors.

c. Techniques for the reduction of track generated noise from earth supported, ballasted track, from concrete track bed structures, and from elevated structures are well known. These include the use of resilient track fastenings such as the "Moses" pad, the Toronto tie-plate isolator and track fastening, the Firestone track fastening, and several European methods which all approach the results of the Toronto design. All of these methods appear to reduce the forces on both car and track and reduce the noise transmitted to surrounding structures. Another effective track noise reduction measure is the use of continuous welded rails. Some rails of this construction are currently installed in the New York Transit System. Some of the "Moses" pad track-isolation units are installed on the shuttle line of the New York Transit System between Grand Central and Times Square. These measures not only reduce noise for people on the outside, but also reduce noise inside the cars, even old, poorly maintained cars.

d. Reduction of the noise from elevated structures requires both track isolation and the damping of the elevated structure. There are some cases where the elevated structure may be improved by appropriate maintenance. However, the usual cause of noise from these structures is the radiation from the large steel plates and girders as well as the unobstructed view of the track provided for nearby neighbors.

e. An approach to track noise reduction in the neighboring areas applied in Toronto and Montreal is the use of sound absorbing panels adjacent to the car, from track bed level up to car door height. The material is also applied under the platform overhang. Such material does not, in general, reduce the radiated noise so that it must be mounted on a rigid lightweight barrier. It is effective, and in combination with track isolation, welded rail and maintenance can produce a subjectively and objectively successful noise reduction in the neighboring residential areas. It is also welcomed by the transit riders. The use of the resilient track fastenings results in reduced vibration being transmitted to nearby buildings along the right-of-way. In Toronto this has resulted in the improvement of noise conditions in theatres and similar spaces in buildings adjacent to the transit line.

f. Both brake squeal and track squeal as trains round curves are under study at the present time. The preliminary results known to some members of this subcommittee indicate that suitable wheel design with the application of certain damping compounds to the wheel disc can reduce or eliminate the noise. Track lubrication can also eliminate wheel squeal, but some transit engineers have reservations about the use of such lubricants because of reduced braking and track surface damage.

g. With respect to passenger car interior noise, the use of fully air-conditioned coaches has virtually eliminated the problem for those lines so equipped. There is little or nothing that can be done for the rider if the window cannot be closed. The use of interior acoustical treatment does offer a slight improvement for those standing in the center of the car, but offers nothing to the seated rider with his ears near the open windows.

h. By far the most significant subway noise reduction has been the use of rubber tires to replace steel wheels as the main traction and support method. Currently in use both in Paris and Montreal, their effectiveness is compared in Fig. 9 showing an 80% reduction in

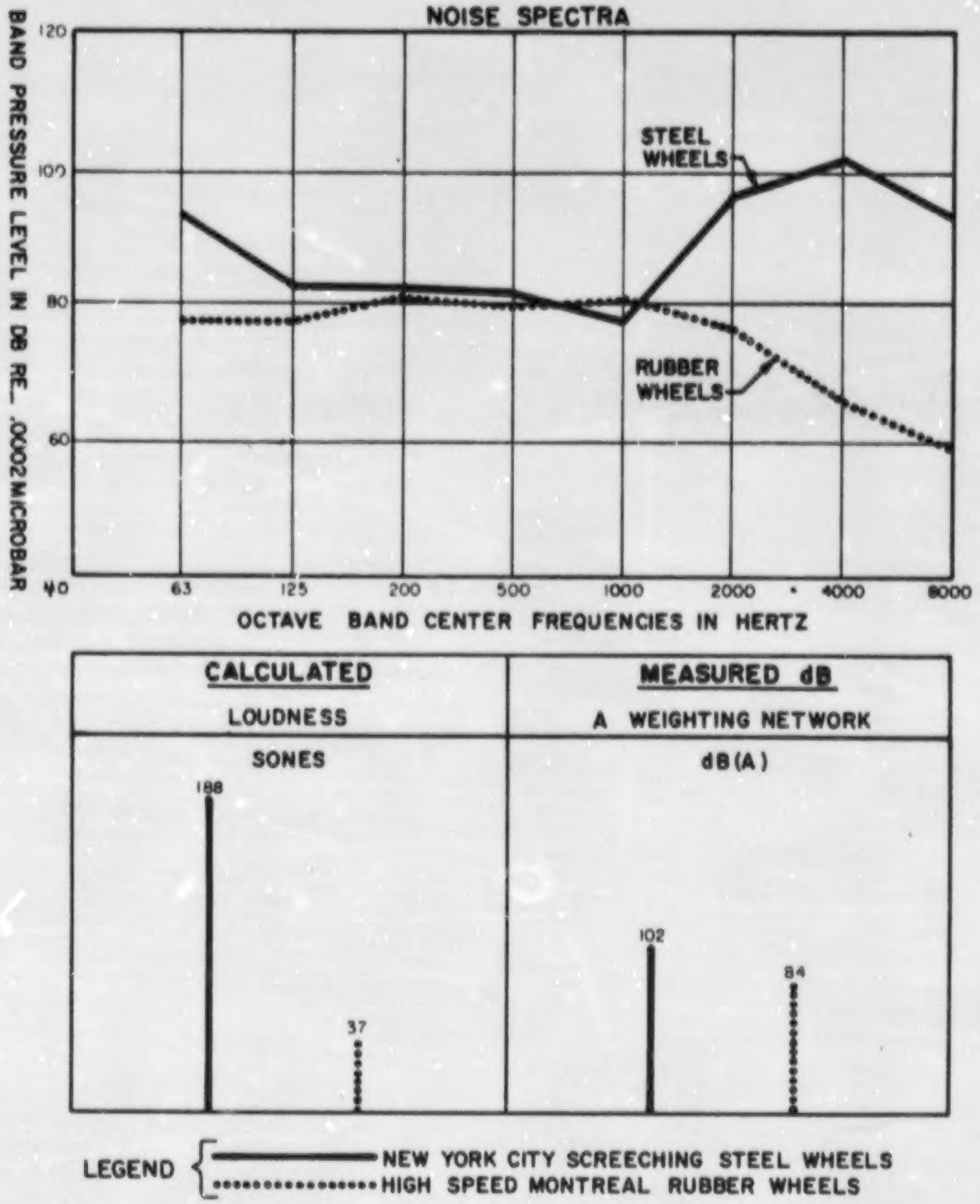

FIGURE 9 SUBWAY NOISE COMPARISON

(Source: Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970)

loudness between New York City's screeching steel wheels at slow speed and Montreal rubber-tired Metro Cars at 55 miles per hour.

2. Truck noise can be minimized through good initial design and through the institution of a uniform muffler code. Maintenance also plays an important role in truck noise control.

   a. An effective regulation with performance standards for truck mufflers would go a long way to eliminate a large part of the unpleasant noise to which City residents living near highways and bridges are exposed. Such performance standards were tried elsewhere over 10 years ago, but did not meet with complete success. The reasons lie in part with the unavailability, at that time, of appropriate electronic sound-measuring equipment for both field and test station use. Today several approaches to performance standards are available, and the electronic equipment for field enforcement is now appropriate for the job.

   b. The work on the reduction of engine noise on diesel buses shows that suitable designs are available for this purpose. Basically all that is required is a sealed engine compartment which is mechanically ventilated by a fan similar to those now employed.

It is even possible that if forced to it, the truck designers might find that the cooling effectiveness of the engine fan may be improved and might even improve the engine operation. If engine and exhaust noise are ever adequately quieted, then it might pay for the manufacturers to look at the transmission and drive noise.

c. Air brake noise, except for the squealing, can be quieted by means of small discharge mufflers and line mufflers located as required by each particular design. Here again, the specification of a performance standard would simplify matters for the truck manufacturer who would then know what the noise control goals were.

d. Refrigeration and air compressors, used for both auxiliary and braking purposes, can readily be quieted by enclosure with suitable quieted forced ventilation and the use of line mufflers to take the pulsations out of the intakes and discharge lines. Here again, with specified performance goals, the job of quieting and enforcement would be considerably easier.

e. The mechanical noises not associated with motive power and drive on trucks can often be quieted by maintenance. Spring and brake rattles are usually

usually indications of poor design or poor maintenance. It is true that an unloaded truck will rattle, note again the truck itself radiates a good part of this noise from the body panels. In fact, much radiation can be reduced in truck-body construction by using better damped structures. This is appropriate for refrigerated trucks and can be effective and economical in panel body trucks to improve structural conditions.

f. Tire noise is a major problem and only a cooperative program among tire and truck manufacturers and the tire re-treading industry to incorporate noise as a major design parameter will produce a quieter tire. At present, with no performance code, there is little strong incentive to develop anything but an economical, low initial cost, long-life tire capable of handling modern day truck loads on our new superhighways at highway speeds. Another possible approach for a major city such as New York is to examine the effect of road surface on both tire noise and safety.

g. The least known source of truck noise is key-jangle noise. This comes from small heavy parts rattling against other parts of the truck. In some situations key-jangle noise can be eliminated by providing spring retainers for the pins and chains required on the truck.

Other measures to quiet these sources could include neoprene or neoprene damped strike plates which would convert the strike noise from a rattle or jangle to a dull thud.

h. Aerodynamic noise is currently not a major problem. Should a number of the other sources listed be quieted, then this source will need attention. The reduction of aerodynamic noise can be accomplished initially in truck design. However, accessories added by the truck or fleet owner or the driver can vitiate any efforts of the manufacturer.

3. Aircraft noise is receiving paramount attention. The solution to this nuisance will require a combination of enlightened regulation and strong municipal pressure on the aircraft industry to engage in a cooperative effort to reduce noise. The New York metropolitan area is economically dependent upon viable air transportation systems, yet anticipated traffic demands have outstripped airport expansion. It is failure to solve the airport noise problems which have led to rejection by the public of proposed new airport capacity. Recent court decisions in Tampa and Jacksonville, Florida, indicate that citizen lawsuits against airport operators have been decided for the complainants and have been upheld in the higher courts.

The lack of success on the part of some of the neighboring municipalities around JFK International Airport in their suit is not indicative of what might occur if another approach to the problem were made by groups of private citizens. The only rational approach is for the City to set what it feels is a desirable long term objective and the acceptable intermediate goals on a fixed timetable. Then the Port of New York Authority and the airlines can be invited to sit down and face the facts. Continued public distaste for noise made by aircraft at the City's two major airports will eventually lead to successful suits against the Port of New York Authority, the airlines or the City. It is recognized by those knowledgeable in this area that all of the technical knowledge is not now available to reduce aircraft noise at the airports to acceptable levels for neighboring citizens and those who live near the low altitude flight paths. However, it seems that a joint research program should be undertaken by the aircraft industry, to determine methods of adequately muffling the jet engine noise over the low-speed - low-altitude phases of flight around the City. It is possible that new engine design and noise suppressors will have to be developed, but until realistic goals are provided to the airlines and enforced, the airlines are unlikely and justifyably so, to fund such a new research program. Funding required for such a program might be provided for by federal funds.

Of the various solutions to the problems listed below, the most economic method or combination of methods must be determined and implemented.

a. Condemning the existing residential land where noise from airport operations is incompatible with residential noise criteria. This involves much larger amounts of money than other methods. Its main disadvantage is the relocation of enormous blocks of population from long well-established communities.

b. Sound proofing residential property around the airport. Though this solution is not as expensive as condemnation, it still is more expensive than other ideas. It is estimated that several thousands of dollars per residence will be required, making such an approach run into several billion dollars. The problems with this solution are that the outdoor noise is still incompatible with residential use, and many residents would object to sealed windows.

c. Quieter aircraft and engine design is a goal long sought, but the noise reudction technology is outstripped by the need for larger aircraft with more powerful engines. There is little likelihood that aircraft technology can alone solve the problem and, even if it did, retrofit costs for the large existing fleet would be extremely expensive and time consuming. Perhaps ten to fifteen years would be a minimum target time for reasonable residential noise levels with existing airport runway locations.

d. Revised aircraft operation holds much promise. If the thrust-to-weight ratio of the aircraft is increased on take-off by:

   1) retrofit with more powerful engines

   2) reduce aircraft load

   3) use auxiliary thrust support (ground based)

   then sufficient aircraft speed can be obtained permitting residential overflight at reduced thrust until over water or compatible land use permits increased thrust for continued climbout. Similarly, a revised landing procedure with a steeper glide path would permit lower thrust and quieter residential overflight. These ideas are met with controversy within the industry, principally, the airline-pilot sectors.

e. Reorienting runways and flight paths so that overflight provides the least number of residences affected. The

FAA requires cooperation from the Port of New York Authority in runway design to make an effective change. This might well prove the most economical solution in terms of both time and money for large blocks of population but not for all residential areas now affected. The air traffic congestion is aggrevated by the close proximity of the two Queens airports.

f. Off-shore airports have been suggested and are seriously being studied as reported in technical journals (AICE and AIAA). Los Angeles, Chicago, New Orleans and Boston all have such plans and like New York City, are blessed with large bodies of water close to the core city. The water depths on the Atlantic Shelf for John F. Kennedy International Airport and Long Island Sound for LaGuardia Airport are on the order of 80 feet or less, practical for:

1) dike-type land reclamation
2) land fill (to ease New York City's solid waste disposal problem)
3) open structural support (technology developed by the oil and gas industry for offshore drilling and processing plants)

Expense is likely to be more than for a land-based airport, but an offshore airport would be less remote than some of the sites the Port Authority is forced to consider largely due to its present record of environmental impact on residential communities.

g. The off-shore runway system, where only the noisy take off and landing operations are moved out into the water, would appear to have real merit. Locating just the runways off shore and connecting them to existing land-based terminals and maintenance facilities with an aircraft taxi-way, has many advantages.

   1) Lower cost than building an entire new airport.
   2) Relatively unlimited space availability and little land acquisition cost.
   3) Parallel runways, three or more, to solve traffic tie ups caused by runway unavailability. The Port Authority has prepared plans for third parallel runways at JFK which involve further expansion into Jamaica Bay, indicating such a need.
   4) Improved air traffic situation because of greatly increased separation between JFK and LaGuardia runway complexes.
   5) Close proximity to the City. Though runway to gate time might be increased 15 to 30 minutes,

it is a lot less delay to the overall city-to-city time than the proposed remote new jetports will cause.

6) Use of existing terminals (currently being expanded for Jumbo-Jet use) as well as aircraft maintenance facilities not only reduces cost but, more important, the construction time.

7) The large land areas now devoted to runway use at New York City airports would be released for quiet industrial parks or similar revenue and job producing use.

Basic economic studies are currently underway by the air industry to provide cost data on some alternatives outlined above. This is a healthy step on the part of an industry which, belatedly, is recognizing that the noise problem is not going to "go away". With an active New York City interest in establishing acoustic criteria for its various zoned areas, the air industries can plan effectively to expand its services in an orderly manner. With an off shore runway complex, it can provide this very necessary transportation service as well as a harmonious environment for the large populations resident in the Bronx, Brooklyn and Queens areas who have been plagued with serious environmental deterioration resulting from New York City's airport operations.

Other airport noise problems originate in ground equipment operation and ground transportation facilities. These sources can be handled by the means discussed for the individual areas of noise control in which they fall.

d) Industrial Noise Control

Sources of noise in industrial operations, whether indoors or out of doors, require the same basic approaches in quieting. The sources will, therefore, be discussed by type of source rather than by source location.

1. Air intakes and discharges from fans and compressors produce noise from three types of sources:
    a. Blade noise.
    b. High velocity air flow noise.
    c. Interior noise passing through the fan opening, which, in this case, acts as a duct.

   In quieting fan noise, it is necessary to consider all three sources. A relative quiet slow speed fan may have a large opening that radiates plant process noise. In this situation, it may be easier to move the fan location or the operation rather than provide a large amount of noise reduction for a relatively quiet fan. Basic treatment for low-to-moderate pressure fans (up to about 10 inches of water pressure) handling large volumes of air is to use a sound trap. Such traps may be fabricated sections of acoustically lined duct, acoustically lined bends, acoustically treated plenums, and pre-fabricated commerical mufflers. The usual acoustical lining materials are glass and mineral wool boards, and blankets. These materials are commercially available for this service and come with various facing materials to accommodate the wide variety of airflow conditions encountered. The basic acoustical requirements include a depth of treatment (blanket thickness) of at least 0.1 wavelengths for the lowest frequency of concern, with a minimum of 1", air passage widths under two feet, and a length of lining adequate to reduce the sound energy to the design value. This may vary from 30 feet for a 2 x 2 ft. duct lined with 1" thick material to 36" for a sound trap fabricated with 4" thick baffles (splitters) 8" on center. In any case the design should be carried out explicitly for each intake or exhaust duct and for each fan. The usual procedure is to measure the noise made by the intake or discharge at a distance suitable for the measurement and calculation of the noise level in the neighboring residential area or the area or zone boundary specified in zoning or nuisance statutes. The background noise level at night may also be required if the criteria are to be based on not annoying the neighbors. With this information, the design noise reduction for the particular muffler can be specified. It must be remembered that where there are several sources the noise from each must be carefully measured in order to assure that it is quieted. Also, the total noise produced by the multiplicity of sources must be considered when evaluating the sound expected at a remote location. High pressure fans may be quieted in a similar manner unless they also operate at high discharge velocities. In this case, the discharge noise may be as noisy as the blade noise. In this case the application of a muffler or pre-fabricated sound trap may increase the noise level at a remote point rather than reduce it. This application may require installation of a special muffler having a pressure and velocity control system in order to provide appropriate air flow conditions for noise control. The mufflers of this type often incorporate both air and noise control in one package. Steam and air discharge lines including high pressure discharge are usually treated with a pressure control discharge muffler which may also include special mechanical properties such as water separation for steam lines.

2. Pumps and compressors generate noise which, although the

flow is fully contained in the piping, radiates directly from the fan or pump casing, the sheet metal ductwork and the rigid piping. It may only be necessary to enclose the offending unit in a sheet metal housing, although it is often easier and more effective to have the unit enclosed in a two to four inch thick sound absorbing and sound isolating housing. The materials of this type needed to fabricate the enclosure can be assembled on the job or can be purchased in built-to-order assemblies, or in stock sizes from half a dozen national manufacturers. In many cases compressor and pump piping remote from the unit radiates the noise. In this situation, good results have been achieved by wrapping the piping or duct with a relatively thick glass fiber blanket and placing a 1 to 2 lb./sq. ft. jacket over the glass fiber. Successful outer wrappers have been sheet metal, impregnated roofing felt (two or more layers) and leaded flexible vinyl sheeting.

3. Direct radiation from pumps, engines and compressors can be minimized by operating these units in suitable enclosures. When correctly enclosed, a railroad car mounted, diesel driven electrical generator that can supply power to an entire community can be located within that community. This is a case where the enclosure has been

designed for the application. Where engines and electrical motors are used to drive the equipment, both engine exhaust treatment and cooling air system noise control measures are required. However, on a production basis, quieting such machines should not increase their cost greatly.

4. There is no excuse for permitting industrial operations to be carried out in an industrial plant with the windows open if the industrial operations generate noise that disturbs the neighbors. Whether the operation must be quieted or else the windows must be closed and forced ventilation used along with appropriate quieting for the new ventilation fans. Fans and ducts inside the plant can be used to create better patterns of air circulation than are usually achieved with open windows alone, and the possibility of using intake filters may improve maintenance and cleaning conditions within the building. Economically marginal businesses balk at the requirement for this type of noise control, but there is no other solution.

5. Where machine operations are heard outside of buildings having no openings, the problem is usually one of vibrations from the machines being radiated by the building walls. The simple and effective means of

metal spring and elastomeric vibration isolators are often available as stock items from a large number of suppliers. The vibration isolators are usually placed between the machines and the floor.

e) Noise Control in Construction

The control of the noise generated by the various engines, pumps, and compressors operated at a construction site involves the same basic methods used in industrial noise control where the same equipment is involved. Of particular importance in construction site noise control is the reduction of noise from equipment which is to operate on a 24 hour-a-day basis. Here the criteria for control must be selected on the basis of nighttime annoyance. The concept among contractors on municipal projects that their work for the City transcends all private rights must be changed. It is unfortunate that it often takes a suit for an injunction by enraged citizens to obtain relief.

The basic methods of achieving noise control on all construction projects in the City, whether for a municipal or other governmental agency, a quasi-governmental authority or a private builder, is the use of a statute or an administrative order requiring that the noise levels be maintained at or below a level specified. Where blasting, pile driving or riverting are to be used, they should be limited to daytime hours.

The City might place a premium on the use of "sonic" pile driving, which although noisy, is less so than the conventional drop-hammer, and on the use of bolted steel construction instead of riveted work in order to induce contractors to use the quieter methods.

The use of special damping techniques along with riveting does not seem promising since such methods usually impose a weight penalty on the riverters equipment. However, the City might get the cooperation of organizations including the New York Building Trades Council, Tishman Research, and the equipment manufacturers to study the problem with some acoustical engineering guidance. It may be that some as yet unexplored methods could reduce noise from riveting.

The noise of men working is a universal problem at construction sites and elsewhere. An effective public relations program can help to reduce personnel generated noise. An effective source of public relations material is a cooperative effort with the various unions. If the union officials will cooperate with the City on this, the benefits to the men and their union will be more jobs and a better public climate. Posters on the job and well briefed foremen help too.

The whole problem of construction safety as well as noise needs better public relations between contractor, union and working force. The problem here appears to be little desire on the part of the contractor to communicate to his temporarily employed work crews. The city could do much for its citizen-workers, its builders and contractors who pay the insurance premiums, and its businessmen-owner-tenants by educating the contractors a guilders to the methods of on-the-job communication with work crews.

The interior finishing and residential wood frame construction noise problem is difficult to attack, but two measures will help:

(a) Limit such activity to daytime hours until a building is fully enclosed.

(b) More frequent use of pre-cut, factory assembled, and prefinished subassemblies in wood frame residential construction.

f) Noise Control for Heating, Ventilating and Air Conditioning Equipment

The basic problems in this field are ignorance, poor communication between client, architect and mechanical engineer, improper budgeting, no incentives. Under a set of circumstances like these, there is little reason for quieter installations to be made in the City.

The knowledge is available to select quiet equipment and design quiet installations. To achieve the result, the City has only to enact the noise control requirements of the proposed building code and to enforce it and the industrial noise criteria proposed elsewhere in this report on all non residential-commercial activities.

The techniques for quieting the equipment are the same as those listed above the industrial equipment. However, in the office and residential air conditioning field, ignorance often wastes the dollars that could buy a quiet installation on excessive system capacity safety factors. Members of the technical subcommittee have seen excessively large fans and cooling towers used in buildings only because the designers were not sure of the operating point for any of the equipment. This always leads to noisy installations at greater expense than the correctly sized one. A fan operating at its most efficient point makes the least noise. When "idling", a fan may make many decibels more noise than the efficient fan at its rated capacity.

Here the City can promote good design and a quieter City by informing builders and owners of the availability of quiet systems and urging them to assess with their engineers and prospective manufacturers of equipment to be used the cost for quiet systems. The City might even consider a penalty for "guessing wrong". Possibly the Building Department might have to set up a review department to act as local suburban building inspectors who can flag the problems for local builders and warn them of previous problems with specific items of bad design. If the private sector cannot police itself in this respect, the City must.

g) Helping Man Control His Own Environmental Noise

Most of the technical sources that man uses and with which he inadvertently makes noise are subject to the same noise control techniques as the industrial noise sources. If a section of the statutes were to include limitations on exterior noise made by home appliances and hand tools, the manufacturers might get the idea that they must reduce the noise. As it is now, most manufacturers look on noise control as desirable but not imperative. As the City has learned already, just initiating the request or specifying quiet refuse trucks produced the needed result within a very short time.

The problem with warning signals and emergency vehicles should be a problem of continuing investigation by the City in the hope that a more suitable device than a siren may be found.

The incidental noises in City life, the sound truck, the loud radio, phonograph or television, these must probably still be regulated by statute to reasonable levels and it must probably still be the province of the patrolman on the beat to use his judgment and persuasiveness to achieve appropriate neighborhood conditions. He will need suitable statutes to guide him and the courts may need guidance from the statute as to the needs of the people and intent of the statute. No catchall phrases and high sounding platitudes will yield the desired result.

VIII. REFERENCES

1. _______________, Toward a Quieter City. A Report of the Mayor's Task Force on Noise Control, New York, 1970.
2. Baron, Robert: The Tyranny of Noise, New York. St. Martins Press, 1970.
3. Beranek, Leo: Acoustic Measurements. New York: John Wiley, 1949.
4. Beranek, Leo and Miller, Layman: The Anatomy of Noise. Machine Design, September 14, 1967, pp. 174-183.
5. Bolt, Beranek, and Newman, Inc: Noise in Urban and Suburban Areas. Washington, D.C.: GPO, 1967.
6. Bragdon, Clifford R.: Noise Pollution - The Unquiet Crisis. Philadelphia: University of Pennsylvania Press, 1971.
7. Campbell, Jon: Measuring Noise. Machine Design, September 14, 1967, pp. 216-224.
8. Fletcher, Harvey: Speech and Hearing in Communication. New York: Van Nostrand, 1965.
9. Franken, Peter and Page, Daniel: Noise in the Environment. Environmental Science and Technology, Volume 6, Number 2, February 1972, pp. 124-129.
10. Hirsh, Ira: The Measurement of Hearing. New York: McGraw-Hill, 1952.

11. Peterson, Arnold and Gross, Ervin: Handbook of Noise Measurement. Concord, Mass.: General Radio, 1972.

12. Pierce, John R. and David, Edward: Man's World of Sound. New York: Doubleday, 1958.

PAGE 83 - APPENDIX -"CHART FOR COMBINING LEVELS OF UNCORRELATED NOISE SIGNALS" - REMOVED PRIOR TO BEING SHIPPED TO EDRS FOR FILMING DUE TO COPYRIGHT RESTRICTIONS.